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The Steel Square

By
I.C.S. STAFF

THE STEEL SQUARE, Parts 1–2

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THE STEEL SQUARE

(PART 1)

Serial 1066A-2 Edition 1

PRINCIPLES OF APPLICATION

DESCRIPTION OF THE SQUARE

1. Among the many tools employed by mechanics, there is probably none so useful as the **steel square.** Notwithstanding the mass of marks and figures, there is nothing about a steel square that is complicated or that requires a knowledge of higher mathematics to enable it to be used in ordinary practice, and after a few hours of careful study and examination, every mark and figure should be clearly understood. There are a number of ways of marking the square, which depends on the design or type and on the purpose for which it is to be used. These markings, however, in no way affect the principles of application, and when these principles are once thoroughly understood, any make of square can be accurately used, provided, of course, that the instrument is true.

2. Parts of a Square.—The long arm of a square is called the **body,** or **blade,** and in referring to this part of the instrument, preference will be given to the name *body*. The short arm is called the **tongue,** and the junction between the body and the tongue, on the outer edge, is called the **heel.** The body of a standard steel square is 24 inches long and 2 inches wide, and the tongue is from 14 to 18 inches long and $1\frac{1}{2}$ inches wide. In some inferior grades of squares

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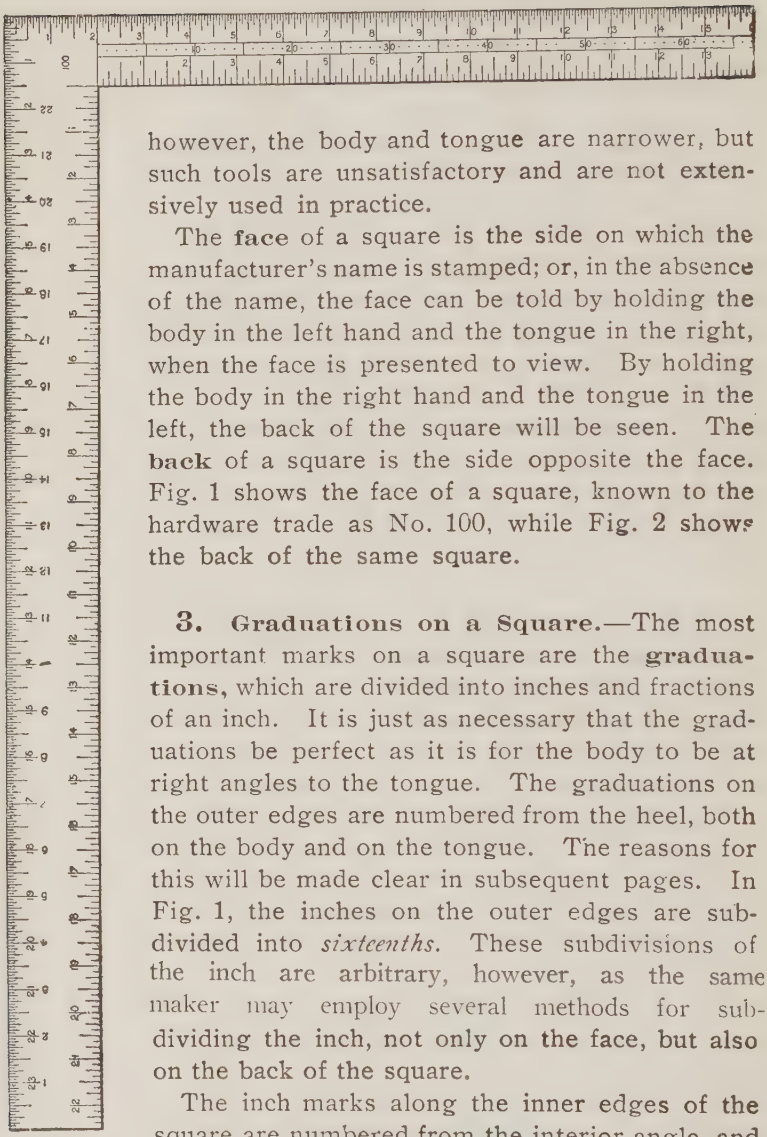

FIG. 1

however, the body and tongue are narrower, but such tools are unsatisfactory and are not extensively used in practice.

The **face** of a square is the side on which the manufacturer's name is stamped; or, in the absence of the name, the face can be told by holding the body in the left hand and the tongue in the right, when the face is presented to view. By holding the body in the right hand and the tongue in the left, the back of the square will be seen. The **back** of a square is the side opposite the face. Fig. 1 shows the face of a square, known to the hardware trade as No. 100, while Fig. 2 shows the back of the same square.

3. Graduations on a Square.—The most important marks on a square are the **graduations,** which are divided into inches and fractions of an inch. It is just as necessary that the graduations be perfect as it is for the body to be at right angles to the tongue. The graduations on the outer edges are numbered from the heel, both on the body and on the tongue. The reasons for this will be made clear in subsequent pages. In Fig. 1, the inches on the outer edges are subdivided into *sixteenths.* These subdivisions of the inch are arbitrary, however, as the same maker may employ several methods for subdividing the inch, not only on the face, but also on the back of the square.

The inch marks along the inner edges of the square are numbered from the interior angle, and in Fig. 1 are subdivided into *eighths.* As the width of the body of a square is in even inches, the inch

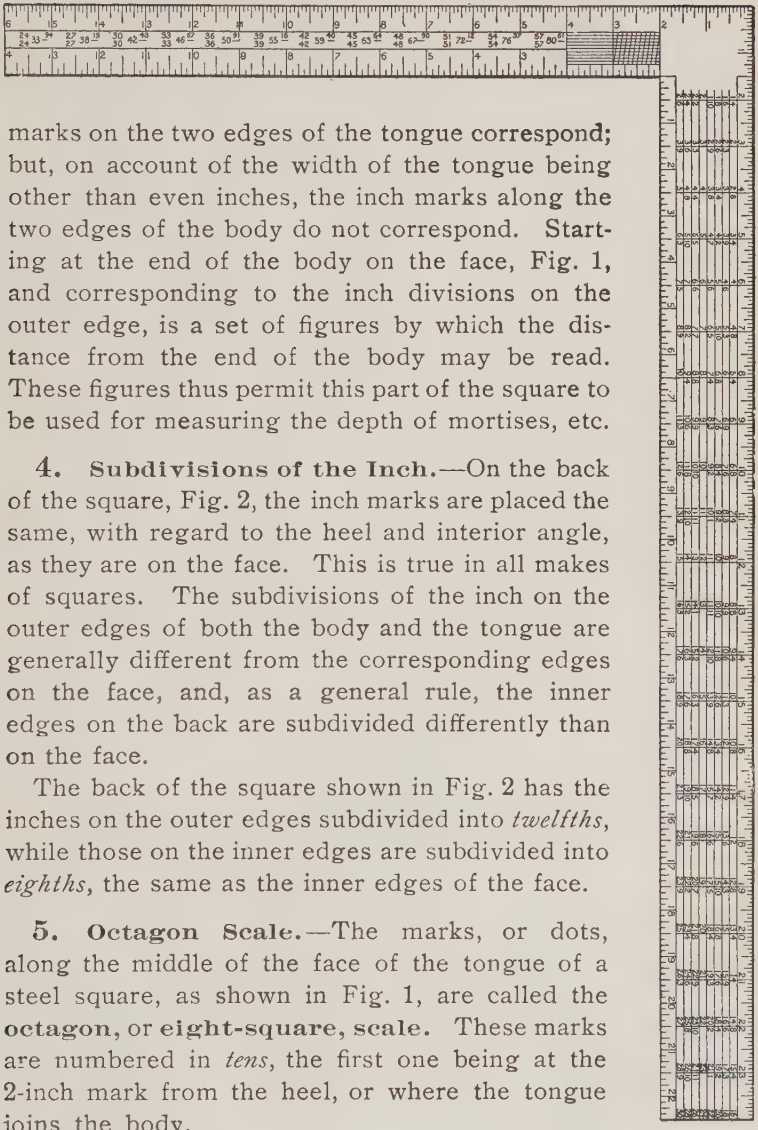

FIG. 2

marks on the two edges of the tongue correspond; but, on account of the width of the tongue being other than even inches, the inch marks along the two edges of the body do not correspond. Starting at the end of the body on the face, Fig. 1, and corresponding to the inch divisions on the outer edge, is a set of figures by which the distance from the end of the body may be read. These figures thus permit this part of the square to be used for measuring the depth of mortises, etc.

4. **Subdivisions of the Inch.**—On the back of the square, Fig. 2, the inch marks are placed the same, with regard to the heel and interior angle, as they are on the face. This is true in all makes of squares. The subdivisions of the inch on the outer edges of both the body and the tongue are generally different from the corresponding edges on the face, and, as a general rule, the inner edges on the back are subdivided differently than on the face.

The back of the square shown in Fig. 2 has the inches on the outer edges subdivided into *twelfths*, while those on the inner edges are subdivided into *eighths*, the same as the inner edges of the face.

5. **Octagon Scale.**—The marks, or dots, along the middle of the face of the tongue of a steel square, as shown in Fig. 1, are called the **octagon**, or **eight-square, scale.** These marks are numbered in *tens*, the first one being at the 2-inch mark from the heel, or where the tongue joins the body.

The octagon scale is used as follows: For instance, it is required to make an octagonal, or eight-sided,

post from a piece of timber 10 inches square. In Fig. 3, *a b c d* is the butt of a square stick of timber 10 in. × 10 in. Scribe the lines *e f* and *g h* through the center, parallel with the sides and at right angles to each other. With the compasses, take as many spaces from the scale as there are inches in the width of the stick. In this case, the stick is 10 inches square; therefore, take 10 spaces and lay off this distance on each side of the point *f*, thus fixing points *a'* and *d'*. In the same manner, locate the points *a''* and *b''*, *b'* and *c'*, and *c''* and *d''*; then, scribe the lines *a' a''*, *b' b''*, *c' c''*, and *d' d''*. Cut off the corners marked *A*, *B*, *C*, and *D*, but before doing so, scribe the lines *a' a'* and *a'' a''* on the sides of the stick, as shown in Fig. 4. The rule always to be observed is as follows:

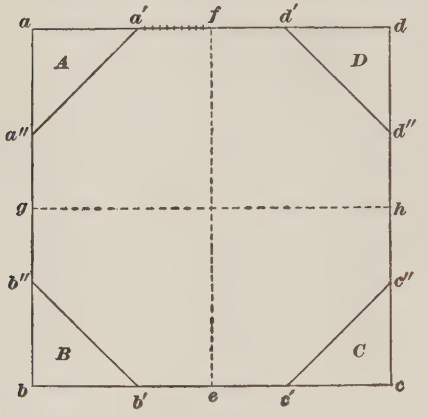

FIG. 3

Rule.—*To make an octagonal post out of a square stick of timber, set off from each side of the center line on each face as many spaces from the octagon scale as the timber is inches square. These points represent the angles of the octagon.*

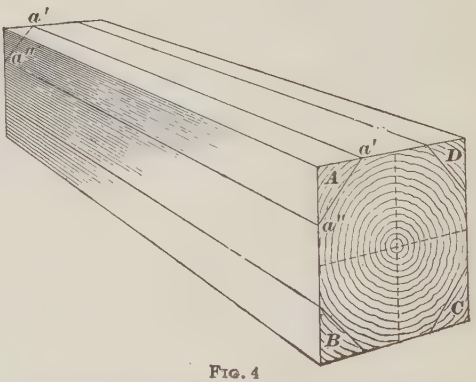

FIG. 4

If the timber is 6 inches square, take 6 spaces from the scale and lay them off as described. Should the timber or other surface be larger than the number of divisions in the

scale, the measurements may be doubled or trebled, as the case may require.

6. Diagonal Scale.—The parallel lines on the back of the tongue of a square, Fig. 2, near the junction with the body, are called the **diagonal scale.** This scale is used for setting the dividers to more minute divisions than the primary divisions of the scale. In Fig. 5, which is an enlarged view of the scale shown in Fig. 2, the scale is first divided into 2 inches by the vertical lines. One of these inch divisions is next subdivided into tenths on the upper and lower horizontal lines, and diagonal lines are drawn, so as to join each upper tenth with the next consecutive lower tenth. The horizontal lines are made $\frac{1}{10}$ inch apart, and as each diagonal line crosses the 10 equal spaces formed by the horizontal lines and advances $\frac{1}{10}$ inch in crossing, it is plain that, for 1 space, it will advance $\frac{1}{100}$ inch. Hence, by scaling from any horizontal line, the required hundredths in addition to the tenths marked above may be obtained.

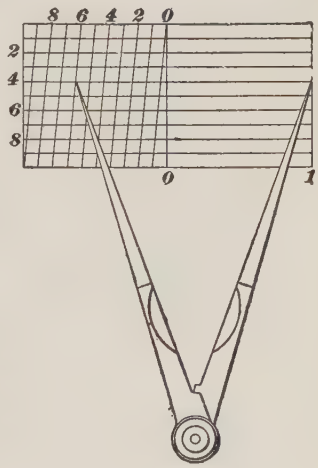

FIG. 5

The dividers shown in the illustration are set to $1\frac{64}{100}$ inches, and this distance is obtained as follows: From *0* to *1* on the lower line is 1 inch, and from *0* to *6* on the upper line is $\frac{6}{10}$ inch; then, by following the diagonal line from *6* to where it crosses the horizontal line marked *4*, $\frac{4}{100}$ inch more is obtained, making the total distance $1 + \frac{6}{10} + \frac{4}{100} = 1\frac{64}{100}$ inches. If, instead of stopping at the horizontal line marked *4*, the dividers are continued down the diagonal line to halfway between the horizontal line marked *4* and the one next below, they will mark $\frac{5}{1000}$ inch more, making the total distance $1\frac{645}{1000}$ inches.

While such minute divisions on the square would not be practicable to use in laying out work on a job, yet the user of a square might possibly want to scale a map, in which case it would be necessary to get these very small divisions. On some squares, the diagonal scale is omitted, and 1 inch graduated into hundredths is substituted.

7. Brace Scale.—The numbers on the middle of the back of the tongue of a steel square, extending from the diagonal scale to the end, as shown in Fig. 2, constitute the **brace scale.** The equal numbers placed one over the other represent the *run*, or, in other words, the two sides of a right triangle, while the numbers at the right represent, in inches and hundredths of an inch, the length of the third side, or hypotenuse. Thus, the exact length of a brace between shoulders having a run of 45 inches on a post and a run of 45 inches on a beam is $63\frac{64}{100}$ inches. These figures are obtained from an inspection of the scale. By referring to Fig. 2, the figures $\frac{45}{45}$ *63.64* will be found, which shows that 63.64 inches is the diagonal, or hypotenuse, of a right triangle having two equal sides each 45 inches long. The figures on the brace scale vary in different makes of squares. On some squares, the run on the post is not always the same as the run on the beam.

8. Scale for Board Measure, or Essex Board Measure. On the back of the body of the square, Fig. 2, is shown the scale for board measure. A thorough knowledge of the use and application of this scale may be gained by studying it for a few minutes, and, when once understood, the contents, in board measure, of almost any board or plank may be read off directly from the scale.

The figure *12* in the graduation marks on the outer edge represents a 1-inch board 12 inches wide, and is the starting point for all calculations. The smaller figures *8, 9, 10, 11, 13, 14,* and *15* under the *12* represent the lengths of boards. The *12* following *11* does not belong to this vertical row of figures, as the contents of a board 12 feet long is read by the

figures on the graduations. For instance, a board 12 feet long and 11 inches wide contains 11 feet, or, a board 12 feet long and 2 inches wide contains 2 feet, the *11* and the *2* being the 11- and the 2-inch figures of the outside-edge graduations.

9. For a practical illustration, suppose that it is required to find the contents of a board 14 feet long and 10 inches wide and 1 inch thick. Under the 12-inch mark on the outer edge of the square will be found the figure *14*, which represents the length. Follow the space in which the *14* is placed back to the row of figures under *10* on the graduations, where will be found the figures *11*|*8*, which is read $11\frac{8}{12}$ board feet, and is the contents of the board. In a like manner, if a board is 14 feet long and 16 inches wide, the result will be found, under the 16-inch mark, to be *18*|*8*, or $18\frac{8}{12}$ board feet. If the board is 2 inches or 3 inches thick, it will be necessary to multiply the contents taken from the scale by 2 or 3, respectively.

The contents of a stick of timber 11 feet long, 10 inches wide, and 8 inches thick is $73\frac{4}{12}$ feet, board measure, and is found thus: Under the 12-inch mark is found *11*; by passing along to the left on the same line to a point below the graduation mark *10*, *9*|*2* is found, which is read $9\frac{2}{12}$ board feet, and is the contents of a board 11 feet long, 10 inches wide, and 1 inch thick. To find the contents of a stick of timber with the same dimensions, but 8 inches thick, all that is necessary is to multiply $9\frac{2}{12}$ board feet by 8, which gives $73\frac{4}{12}$ board feet.

10. By combining figures, the contents of boards, planks, or timber of greater lengths than those shown on the scale can be calculated. Thus, for a board 20 feet long, double the figures in the 10-foot row, and if the board is 2 inches thick, multiply the result by 2. To find the contents of a board 25 feet long, add the figures in the 12- and 13-foot rows.

With the foregoing examples as a guide, it should be possible to work out any number of combinations and thus find the contents of a stick of any size. It should be

remembered that this measure is calculated, as its name indicates, for **board measure**—abbreviated B. M.—which is the surface of a board 1 inch in thickness, 1 foot B. M. meaning a board 1 foot long, 1 foot wide, and 1 inch thick.

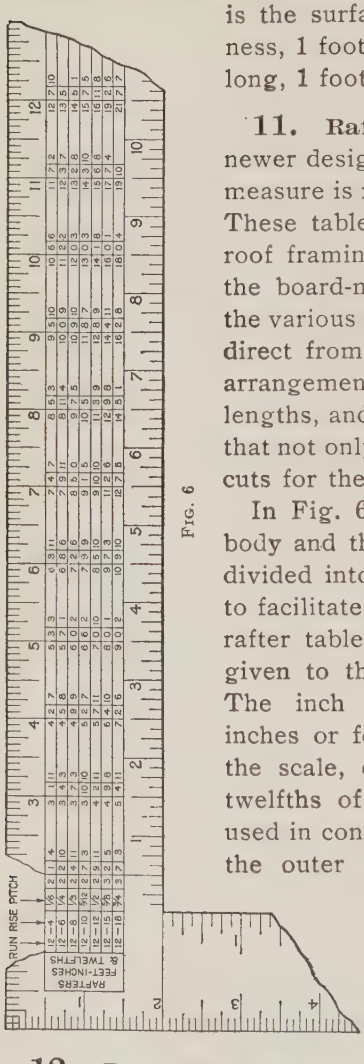

FIG. 6

11. Rafter Tables.—In some of the newer designs of steel squares, the board measure is replaced by the **rafter tables.** These tables are very convenient, and in roof framing are much more useful than the board-measure scale, as the cuts for the various members of a roof may be read direct from the scale. Fig. 6 shows one arrangement of the scale, giving the lengths, and Fig. 7 shows an arrangement that not only gives the lengths but also the cuts for the several members of the roof.

In Fig. 6, the outer edge of both the body and the tongue has the inches subdivided into *twelfths*. This subdivision is to facilitate measurements taken from the rafter table, as all the measurements are given to the nearest twelfth of an inch. The inch marks may represent either inches or feet, and the twelfth marks on the scale, either twelfths of an inch or twelfths of a foot. The rafter table is used in connection with the inch marks on the outer edge of the square. These figures represent one-half the span of the building, or the run of the rafter in feet or inches. The 6-inch graduation may be either 6 feet or 6 inches.

12. Run, Rise, and Pitch.—In the first column of the table, Fig. 6, at the heel of the square, the figures are all *12*, which may be used to indicate either 12 inches or 12 feet.

These figures represent the **run** of a rafter, which is the horizontal distance from the extreme end of the foot to a plumb-line hung from the ridge.

The figures in the second column represent the various *rises*. If 12 inches is used for the run, the various rises are read in inches, and if 12 feet is used for the run, the rises are read in feet. The **rise** is the vertical distance from the top of the ridge to the level of the plate.

The figures in the third column, expressed in fractions, represent the various pitches. The **pitch** is the proportion that the rise bears to the whole width of the building.

13. How to Use the Rafter Tables.—The three columns of figures just mentioned show that a rafter with a run of 12 and a rise of 4 has a $\frac{1}{6}$ pitch; with a run of 12 and a rise of 6, a $\frac{1}{4}$ pitch; and so on to the bottom of the columns. The span of a building with a run of 12 feet is 24 feet, and if the pitch is $\frac{1}{6}$, the rise will be $\frac{1}{6} \times 24 = 4$ feet.

To illustrate the use of the tables, a $\frac{1}{6}$-pitch roof having a run of 9 feet will have a span of 18 feet and a rise of $\frac{1}{6} \times 18 = 3$ feet. To find the length of a rafter for a roof of that width and pitch, look in the column under Pitch and find $\frac{1}{6}$; then follow the parallel ruling until the column of figures under the graduation marked *9* is reached. Here will be found the length of the rafter, which is *9 | 5 | 10*, or 9 feet $5\frac{10}{12}$ inches.

To find the length of a rafter for a building with a 24-foot span and $\frac{1}{2}$-pitch roof, proceed as follows: The run of the rafter will be 12 feet; then look in the column under Pitch for $\frac{1}{2}$, follow the parallel ruling from this point to the column under *12*, and the figures *16 | 11 | 8*, or 16 feet $11\frac{8}{12}$ inches, will indicate the length of rafter to be used.

14. When the run is expressed in inches, then, in the rafter table, read inches and twelfths instead of feet and inches. If, with a $\frac{3}{4}$-pitch roof the run is 10 feet 4 inches, add the rafter length for 10 feet to that of 4 inches. The rafter length for a 10-foot run and a $\frac{3}{4}$ pitch is 18 feet and $\frac{4}{12}$ inch; for 4 inches the length is $7\frac{3}{12}$ inches. Adding the

two lengths gives for the total length of the rafter 18 feet $7\frac{7}{12}$ inches. The inches are obtained in the following manner: Under *4*, in the same line as $\frac{3}{4}$, is found the numbers *7 | 2 | 6*; *7* stands for inches, *2* for $\frac{2}{12}$ inch, and *6* for $\frac{6}{12}$ of $\frac{1}{12}$ inch. Since $\frac{6}{12}$ is $\frac{1}{2}$, it is read as $\frac{1}{12}$ more, thus making $7\frac{3}{12}$ inches for the length of the 4-inch run. In the column under *10*, calling the run 10 inches, the lengths for the several pitches, in inches, reading down the column, are $10\frac{7}{12}$, $11\frac{2}{12}$, 12, 13, $14\frac{2}{12}$, 16, and 18.

THE NICHOLS SQUARE

15. Fig. 7 shows a portion of the body of a steel square, known as the **Nichols square**, on which is a table giving the lengths of common rafters, hip, or valley, rafters, and jack-rafters; also, the cuts for the rafters and sheathing. The inch marks on the top edge are used, in connection with the table, to represent the rise per foot. The 6-inch mark means 6 inches rise for 12 inches run, and the columns of figures under the inch marks refer to the lengths and cuts pertaining to that particular rise.

16. The first line of figures on the Nichols square, Fig. 7, gives the length of the common rafter per foot of run, and is used in this way: It is required to find the length of the common rafters for a roof with a span of 16 feet and a rise of 10 inches per foot of run, which is equal to a $\frac{5}{12}$ pitch. The run of a rafter for a building 16 feet wide is 8 feet. Under *10* in the first line are the figures *15 | 62*, or 15.62 inches, which is the length of the common rafter for a 1-foot run; then, for an 8-foot run, multiply 15.62 by 8, which gives 124.96 inches, or 10 feet 4.96 inches, which is the length of the common rafters.

17. The second line of figures in Fig. 7 gives the length of hip or valley rafters per foot of run. To find the length of hip or valley rafters having the same dimensions as the common rafters just mentioned, that is, an 8-foot run and a 10-inch rise per foot, look in the column headed *10*, and

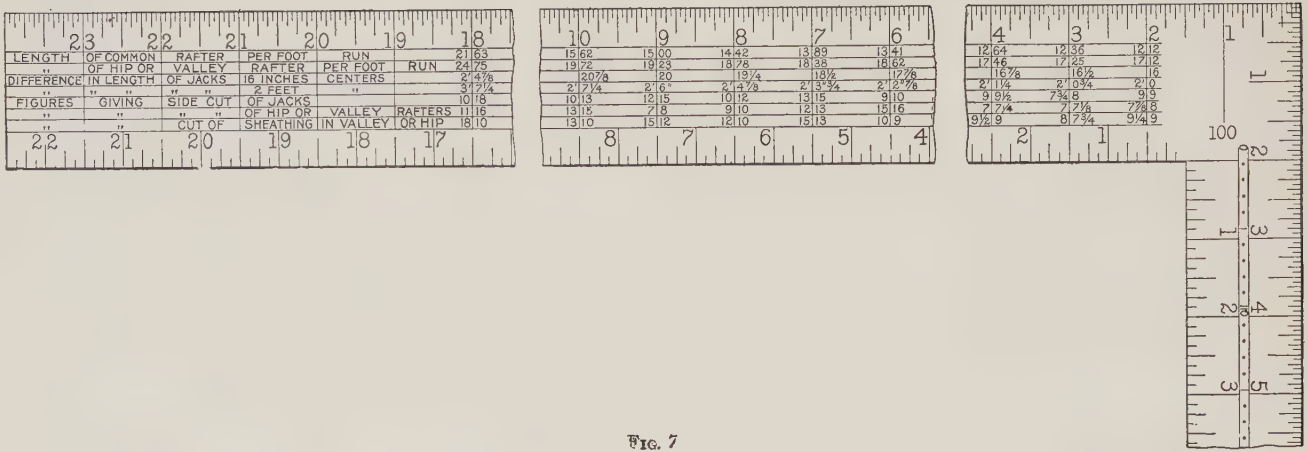
23 22 21 20 19 18
LENGTH OF COMMON RAFTER PER FOOT RUN 21 16 3
" OF HIP OR VALLEY RAFTER PER FOOT RUN 24 17 5
DIFFERENCE IN LENGTH OF JACKS 16 INCHES CENTERS 2' 4 7/8
" " " " 2 FEET " 3' 1 7/8
FIGURES GIVING SIDE CUT OF JACKS 10 18
" " " " OF HIP OR VALLEY RAFTERS 11 16
" " CUT OF SHEATHING IN VALLEY OR HIP 18 10
22 21 20 19 18 17
10 9 8 7 6
15 62 15 00 14 42 13 89 13 41
19 72 19 23 18 78 18 35 18 62
20 7/8 20 19 1/4 18 1/2 17 7/8
2' 7 1/4 2' 6" 2' 4 7/8 2' 3" 3/4 2' 2" 7/8
10 13 12 15 10 12 13 15 9 10
13 15 7 8 9 10 12 13 15 16
13 10 15 12 12 10 15 13 10 9
8 7 6 5 4
4 3 2 1
12 64 12 36 12 12
17 46 17 25 17 12
16 7/8 16 1/2 16
2' 1/4 2' 0 3/4 2' 0
9 9 1/2 7 3/4 8 9 9
7 7/4 7 2 1/2 7 7/8 8
9 1/2 9 8 7 3/4 9 1/4 9
2 1
100
1 1
2 3
1 2
4 3
2 5
3

Fig. 7

directly under *15 | 62* will be found the figures *19 | 72*, or 19.72 inches. Then, multiplying these figures by the run of the common rafter, or 8 feet, will give the desired length. Thus, $19.72 \times 8 = 157.76$ inches, or 13 feet 1.76 inches.

18. The third line of figures gives the length of the first jack-rafter and the difference between the length of the other jack-rafters when spaced 16 inches on centers. For example, the first jack-rafter on a hip in the foregoing example will be $20\frac{7}{8}$ inches, the figures being obtained from the third line in the column headed *10* The length of the second jack-rafter will be $20\frac{7}{8} + 20\frac{7}{8} = 41\frac{6}{8}$ inches, and of the third jack-rafter, $41\frac{6}{8} + 20\frac{7}{8} = 62\frac{5}{8}$ inches.

19. The fourth line in Fig. 7 gives the length of jack-rafters placed 2 feet on centers, and is used in the same manner as the third row. If placed on 2-foot centers, the first jack-rafter will be 2 feet $7\frac{1}{4}$ inches long.

20. The fifth line of figures in Fig. 7 gives the side cuts of jack-rafters that fit against hip or valley rafters. The side cut for jack-rafters in the foregoing case is 10 inches on the body and 13 inches on the tongue of the square, the tongue giving the cut. To obtain these figures, look at the fifth line under *10*, and there will be found *10 | 13*; the first figure *10* has reference to the distance from the heel of the square on the body, which is 10 inches, and the second figure *13* has reference to the distance from the heel on the tongue, which is 13 inches.

21. The sixth line of figures in Fig. 7 gives the side cuts of hip or valley rafter against the ridge board, or deck, and is used in the same manner as the figures that give the side cuts of jack-rafters. The figures *13 | 15*, in the column headed *10*, mean 13 inches on the body and 15 inches on the tongue of a square, the tongue giving the cut.

22. The seventh line of figures in Fig. 7 gives the cuts of sheathing and shingles in valleys or on hips. In the column headed *10* will be found the figures *13 | 10*. By placing the square on the material to be cut so that the

figures *13* on the body and *10* on the tongue will intersect one edge, and cutting along the tongue, the correct cut for sheathing or shingles will be obtained.

23. The jack-rafter marks on the Nichols square, Fig. 7, will also give a number of other cuts useful in roof framing. The figures on the square giving side cuts of jack-rafters will also give the miter cuts for moldings in the valley at the junction of two gables, and will give the miter cuts for gable moldings where they intersect with level moldings at the end of a building.

The figures giving cuts of sheathing for valleys or hips will give cuts for mitering level planchers with gable planchers, also the miter cuts where two gable planchers intersect, and the cut for a plancher on the gable end.

In addition to the rafter tables, the Nichols square illustrated in Fig. 7 also has the brace scale, the octagon scale, and 1 inch subdivided into hundredths.

ORDINARY STEEL SQUARE

24. While the tables and scales described in the preceding articles are very useful and convenient and may be relied on as being correct, there is not a single framing problem likely to arise in practice that cannot be solved by means of an ordinary steel square with only the graduations marked on the edges, provided the graduations are true and the body and tongue are at right angles to each other. The importance of having a square true will be made clear in the following pages.

25. **Testing a Square.**—In order to test a square to see that the body and tongue are at right angles, take a board 12 inches or more in width and at least 4 feet in length, surface it on one side, and true up one edge so as to be perfectly straight. Place the square as shown at *a*, Fig. 8, and mark the board along the tongue both on the outer and on the inner edges; then reverse the square as shown at *b*, and if the outer edge of the tongue coincides with the mark

made on the outer edge of the tongue in *a* it is proof that the inner edge of the body is at right angles to the outer edge of the tongue. If, by moving the square *b* over to the right until the outer edge of the tongue comes to the mark made

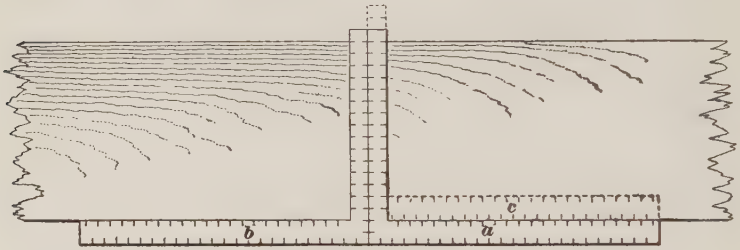

FIG. 8

along the inner edge of the tongue in *a*, the edge and the mark coincide, it is proof that the inner edge of the tongue is at right angles to the inner edge of the body, and also that the two edges on the tongue are parallel

26. In a like manner it can be shown that the outer edge of the body is at right angles to the tongue or that the two edges of the body are parallel. To do so, move the square *a* until the outer edge of the body coincides with the straight edge of the board, as shown at *c*, Fig. 8. Then, if this edge is at right angles to the tongue, the tongue will coincide with the marks, provided, of course, that the square in the first case was true with regard to the edges. If any of the edges are not true, they may be made so by filing or

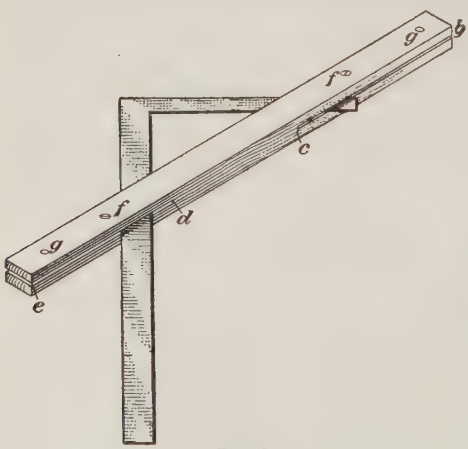

FIG. 9

grinding the tongue or the body until at right angles, using the marks on the board as a gauge, or templet.

27. The Fence.—In Fig. 9 is shown an adjustable fence with the square set. A fence consists of a strip of hardwood—cherry or black walnut being preferable—about 2 inches wide, $1\frac{1}{2}$ inches thick, and from $2\frac{1}{2}$ to $2\frac{5}{6}$ feet long. Saw kerfs *b c* and *d e* are cut in from each end, leaving from 6 to 8 inches of solid wood in the center, as shown at *c d*. Two holes *f* and *g* are bored through each end, and two screws are inserted, as shown at *f*, to bind the fence on the square.

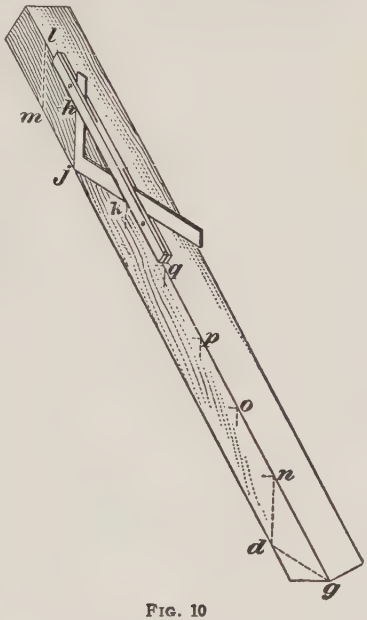

FIG. 10

Fig. 10 shows the method of using the fence. The body and tongue are clamped fast at the run *k, j* and rise *j, h*; then, if the fence and square are applied to a rafter the correct number of times, the length and the top and bottom cuts for the rafter will be obtained. The letters *g* and *d* show the foot-cut; *n, o, p, q, k, h*, and *l*, the marks used to obtain the length of the rafter; and *l* and *m*, the top cut.

APPLICATION OF THE SQUARE

PRACTICAL METHODS

28. While the octagon scale, diagonal scale, brace scale, and board measure on a square are very convenient, they are not absolutely necessary, and after becoming thoroughly conversant with the principles underlying the use of the steel square, the scales will be found of little use. The same might also be said of the rafter tables. There are many other ways of obtaining the information contained in the scales and tables on a square, and some of these methods will now be explained.

29. Framing an Octagonal Post From a Square Timber.—In Fig. 11 is shown an end view of a stick of timber 10 inches square that is to be marked so that an octagonal post can be cut from it. To find the required lines, lay the square on the two diagonals and mark the lines $a\,c$ and $b\,d$. Measure the distance $b\,e$, which is one-half $b\,d$, and lay off this distance on $b\,a$ and $b\,c$, marking the points a'' and c'; these two points will then be two corners of the octagon. In the same manner, lay off the distance $b\,e$ from a, d, and c, marking the points b'' and d', a' and c'', and d'' and b'. Draw lines $a''\,a'$, $d'\,d''$, $c''\,c'$, and $b'\,b''$, and thus complete the octagon. This method may also be employed in laying out octagons on large plans or on the ground.

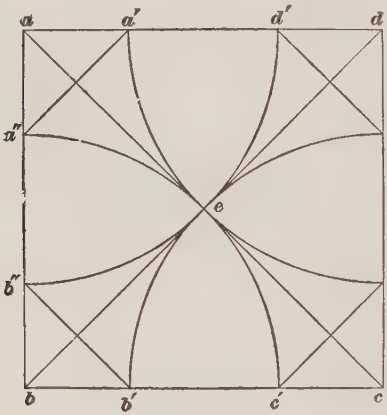

FIG. 11

30. Another method of finding the points for an octagon on a square stick of timber is illustrated in Fig. 12, where *a b c d* represents the end section of a piece of square timber.

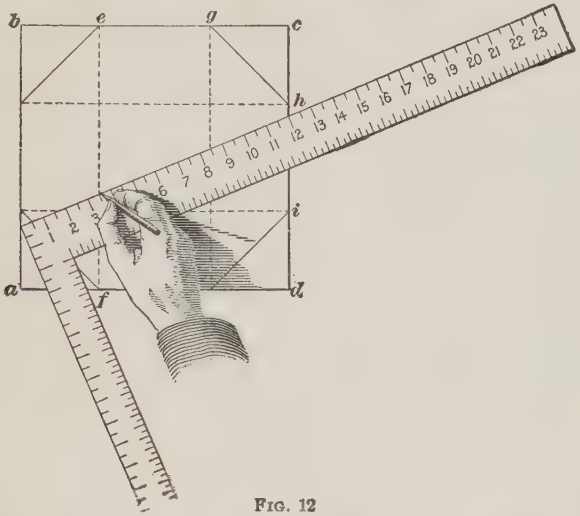

FIG. 12

Lay the steel square on the timber in such a way that any twenty-four divisions on the square will be contained between two parallel sides, and then mark off seven divisions from both sides. In the figure, the heel of the square is placed at one side and the 12-inch mark at the other,

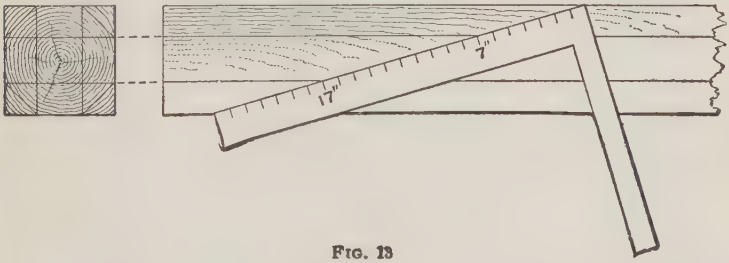

FIG. 13

making twenty-four half-inch divisions. On one side, the seven divisions will therefore come at the $3\frac{1}{2}$-inch mark, and on the other at $12 - 3\frac{1}{2} = 8\frac{1}{2}$ inches, or the $8\frac{1}{2}$-inch mark. If the 6-inch mark is used for a diagonal width, then each

division will be equal to $\frac{1}{4}$ inch, and the marks will come at $1\frac{3}{4}$ and $4\frac{1}{4}$ inches, respectively.

Fig. 13 shows the same principle applied to the side of the timber. The full length of the body of the square is used—thus making each division 1 inch—and the gauge marks come at 7 and 17 inches, respectively.

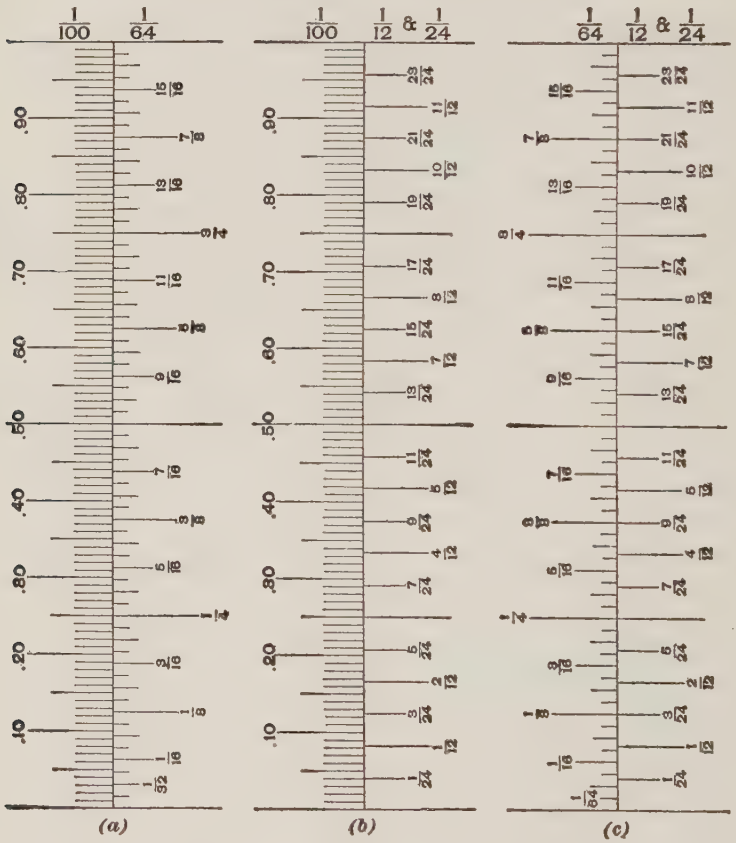

FIG. 14

31. Decimal Scale.—One one-hundredths ($\frac{1}{100}$, or .01) inch is a very small division, and one that is practically impossible to use on the edge of a square. The decimal division of the inch, however, is very convenient for calculations

TABLE I

DECIMALS OF AN INCH FOR EACH 64TH AND 24TH

Decimal	Fraction	32ds	64ths	12ths	24ths	Decimal	Fraction	32ds	64ths	12ths	24ths
.0156			1			.5156			33		
.0312		1	2			.5312		17	34		
.0417					1	.5417					13
.0469			3			.5469			35		
.0625	$\frac{1}{16}$	2	4			5625	$\frac{9}{16}$	18	36		
.0781			5			.5781			37		
.0833				1	2	.5833				7	14
.0937		3	6			.5937		19	38		
.1094			7			.6094			39		
.125	$\frac{1}{8}$	4	8		3	.625	$\frac{5}{8}$	20	40		15
.1406			9			.6406			41		
.1562		5	10			.6562		21	42		
.1667				2	4	.6667				8	16
.1719			11			.6719			43		
.1875	$\frac{3}{16}$	6	12			.6875	$\frac{11}{16}$	22	44		
.2031			13			.7031			45		
.2083					5	.7083					17
.2187		7	14			.7187		23	46		
.2344			15			.7344			47		
.25	$\frac{1}{4}$	8	16	3	6	.75	$\frac{3}{4}$	24	48	9	18
.2656			17			.7656			49		
.2812		9	18			.7812		25	50		
.2917					7	.7917					19
.2969			19			.7969			51		
.3125	$\frac{5}{16}$	10	20			.8125	$\frac{13}{16}$	26	52		
.3281			21			.8281			53		
.3333				4	8	.8333				10	20
.3437		11	22			.8437		27	54		
.3594			23			.8594			55		
.375	$\frac{3}{8}$	12	24		9	.875	$\frac{7}{8}$	28	56		21
.3906			25			.8906			57		
.4062		13	26			.9062		29	58		
.4167				5	10	.9167				11	22
.4219			27			.9219			59		
.4375	$\frac{7}{16}$	14	28			.9375	$\frac{15}{16}$	30	60		
.4531			29			.9531			61		
.4583					11	.9583					23
.4687		15	30			.9687		31	62		
4844			31			.9844			63		
.5	$\frac{1}{2}$	16	32	6	12	1.0000	1	32	64	12	24

and if understood better by the average mechanic would no doubt be used more in the graduations of scales. Probably the best way to fully comprehend the value of $\frac{1}{100}$ inch would be to compare it by illustration with the twelfth and sixty-fourth divisions. In Fig. 14 (*a*), the decimal divisions of an inch are compared with the sixty-fourth divisions, at (*b*) they are compared with the twelfth and twenty-fourth divisions, while at (*c*) the sixty-fourth divisions are compared with the twelfth and twenty-fourth divisions.

In Fig. 14, the inch is enlarged to four times its actual size, thus making the subdivisions easy to read. As an example, take eighty-seven one-hundredths inch (.87 inch), and it is found to equal $\frac{7}{8}$, or $\frac{21}{24}$, inch. Or, suppose a measurement of .39 inch is given; by referring to the $\frac{1}{100}$ scale, it will be found that this measurement is equal to $\frac{25}{64}$ inch. The eye catches the figures on the scale more quickly than those in a table.

The comparison of the several divisions of the inch are also given in Table I.

LAYING OUT BRACES

32. The length of braces may be obtained with a steel square without the aid of a brace scale. While the brace scale gives only a very few lengths—and these are generally of equal runs and rises—the following methods will give the length of any brace with equal run and rise, also the lengths of braces with unequal run and rise. The length of a brace is equal to the hypotenuse of a right triangle. If the run and the rise are equal, as in Fig. 15, all that is necessary is to multiply the run by the constant 1.4142. This method is really quicker than measuring along the tongue and body of the square. The constant 1.4142 is equal to the

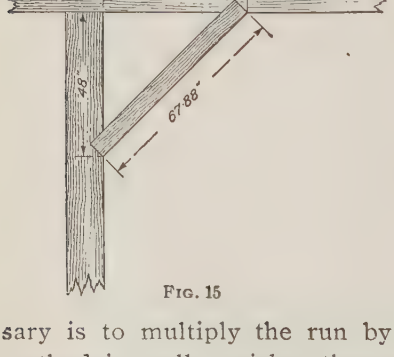

FIG. 15

diagonal from 12 inches on the tongue to 12 inches on the body. Expressed in inches, the diagonal is $1.4142 \times 12 = 16.9704$.

The constant 1.4142 plays a very important part in roof framing. For instance, if the diagonal of 12 inches and 12 inches is 1.4142 feet, or 16.97 + inches, the diagonal of any other equal distances at right angles to each other may be found by multiplying one of the distances by the constant 1.4142.

EXAMPLE.—The rise on a post is 4 feet and the run on the girder is 4 feet. What will be the length of the brace?

SOLUTION.—The length of the brace is found by multiplying one of the distances by the constant 1.4142. Thus, 1.4142×4 ft. = 5.6568 ft. Reducing this to inches it becomes $5.6568 \times 12 = 67.88$ in. Ans.

This same result may be obtained by the following methods: 1.4142×48 in. = 67.88 in.; or, 16.97×4 ft. = 67.88 in.; or, 16.97×48 in. = 814.56, then, $814.56 \div 12 = 67.88$ in. It will thus be seen that feet or inches may be used, either in the diagonal or in the run or rise.

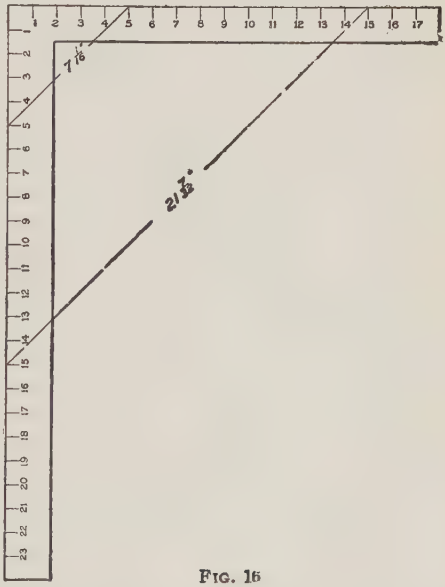

FIG. 16

33. Fig. 16 shows a method of obtaining the length of a brace by measuring the diagonal between the run and the rise. The length of a brace with an equal run and rise of 65 inches is required. As 65 is beyond the limits of the square, it will be necessary to use multiples of 65 or multiples of a part of 65. Take 60 and 5; the 5 is within the limits of the square, and the 60 may be brought within the limits by dividing by 4; thus, $60 \div 4 = 15$. Then, to obtain the length, measure the diagonal, or *bridge measure*, between

15 inches on the tongue and 15 inches on the body of the square. Multiply this distance by 4, because $4 \times 15 = 60$. Now, measure the diagonal between 5 inches on the tongue and 5 inches on the body of the square, and add this distance to the length of the diagonal of 15 and 15 multiplied by 4. The diagonal of 15 and 15 is found to be $21\frac{7}{32}$ inches, and that of 5 and 5 is $7\frac{1}{16}$ inches; $21\frac{7}{32} \times 4 = 84\frac{28}{32}$, and $84\frac{28}{32} + 7\frac{1}{16} = 91\frac{15}{16}$ inches, which is the length of the brace. These figures may be proved by multiplying 1.4142 by 65 inches.

34. The length of the foregoing brace may also be found by taking the run in feet; 65 inches is equal to 5 feet 5 inches, or $5\frac{5}{12}$ feet. By measuring the diagonal from $5\frac{5}{12}$ inches on the tongue to $5\frac{5}{12}$ inches on the body of the square, and calling the measurement feet, it is found to be $7\frac{8}{12}$ feet, or 92 inches long; but 92 inches is $\frac{1}{16}$ inch longer than in the first case. The diagonal of $5\frac{5}{12}$ and $5\frac{5}{12}$ is not exactly $7\frac{8}{12}$ inches, however, but is near enough for most practical purposes.

Nearly all the better makes of squares have one edge of the body and one edge of the tongue graduated into twelfths of an inch and by reading the inches as feet, the twelfths of an inch will represent inches; thus, half of a twelfth would equal $\frac{1}{2}$ inch. If the run and rise were $8\frac{1}{2}$ feet, the length of the brace could be found by taking $8\frac{6}{12}$ inches on the body and $8\frac{6}{12}$ inches on the tongue and measuring the diagonal, which would be found to be 12 inches and $\frac{1}{4}$ of $\frac{1}{12}$ inch long. Calling the inches feet, the length of the brace would be 12 feet and $\frac{1}{4}$ inch.

In braces of equal run and rise, the top and the bottom cuts are at 45°, provided that the brace is between two timbers at right angles to each other. The cuts are obtained by taking any equal numbers on the body and tongue of the square.

35. Another method of finding the length of a brace is to take the length of the run on the tongue and the length of the rise on the body of the square and apply the square

to the brace the same number of times as there are feet in the run. When using the square in this manner, however, the 12-inch mark is used on the tongue or body for the run.

Fig. 17 shows a brace between a post and a beam. The run and the rise are each 3 feet 6 inches. It will be observed

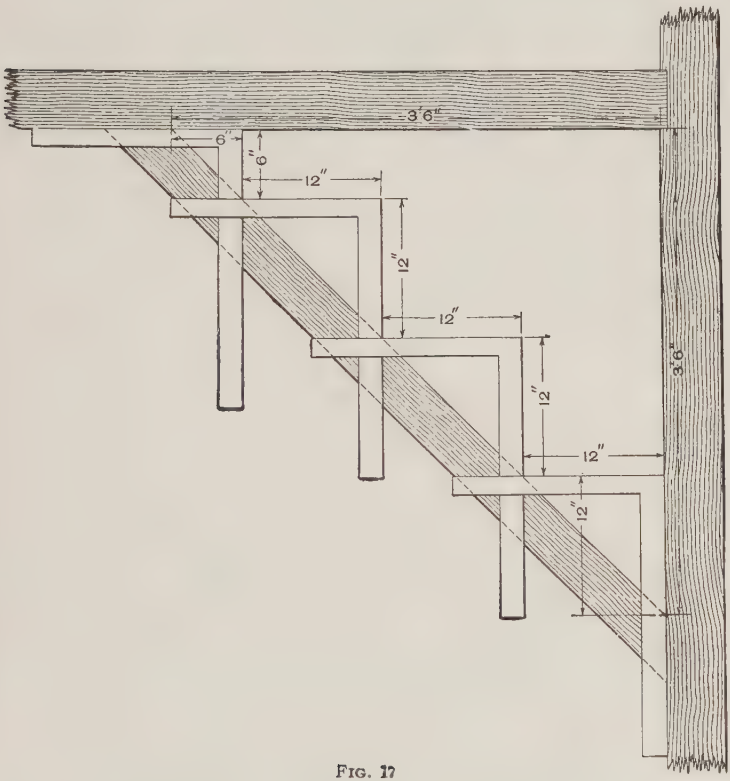

FIG. 17

that the body of the square gives the line for the cut along the post, and that the tongue of the square gives the cut along the beam.

36. Fig. 18 shows a brace in which the run is less than the rise; consequently, the brace does not form an angle of 45° with the post. The length may be found by multiplying

the diagonal, or bridge measure, between 12 and 9 by the rise, because the brace rises 12 inches for every 9-inch run. The length may also be found by applying the square as shown in Fig. 17.

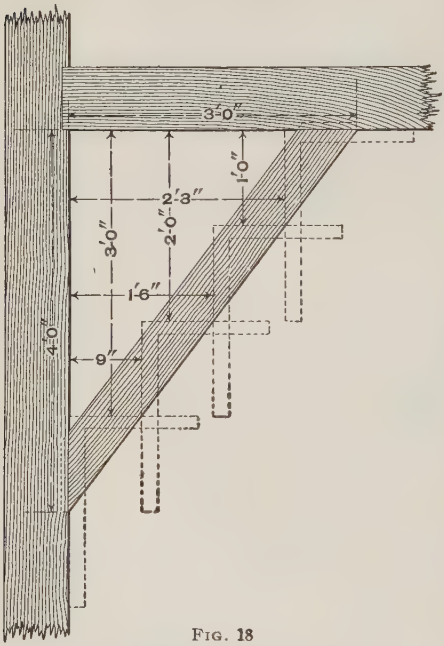

FIG. 18

In the brace shown in Fig. 18, the rise is 4 feet and the run is 3 feet. By taking 12 inches on the body and 9 inches on the tongue and applying the square four times, the length of the brace will be found. The body of the square gives the cut to fit against the post, and the tongue of the square gives the cut to fit against the beams. By measuring from the 4-inch mark on the body to the 3-inch mark on the tongue, and calling the inches feet, it will be found that the brace is 5 feet long; or, again, by measuring from 12 inches on the body to 9 inches on the tongue and multiplying the distance by 4, the length of the brace will be in inches. The bridge measure of 12 and 9 inches is 15 inches, and 15 inches $\times$ 4 = 60 inches, or 5 feet.

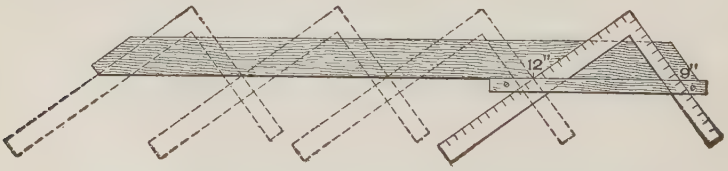

FIG. 19

37. Fig. 19 shows the way to apply a square to get the length and the top and bottom cuts of a brace.

38. Fig. 20 shows a method of getting the length and cuts in cross-bracing. In this illustration, the top and bottom timbers are 12 feet apart, and the distance between centers of the braces at both top and bottom is 10 feet. By calling 10 feet the run and 12 feet the rise, and using these distances on the tongue and body of the square, it will be

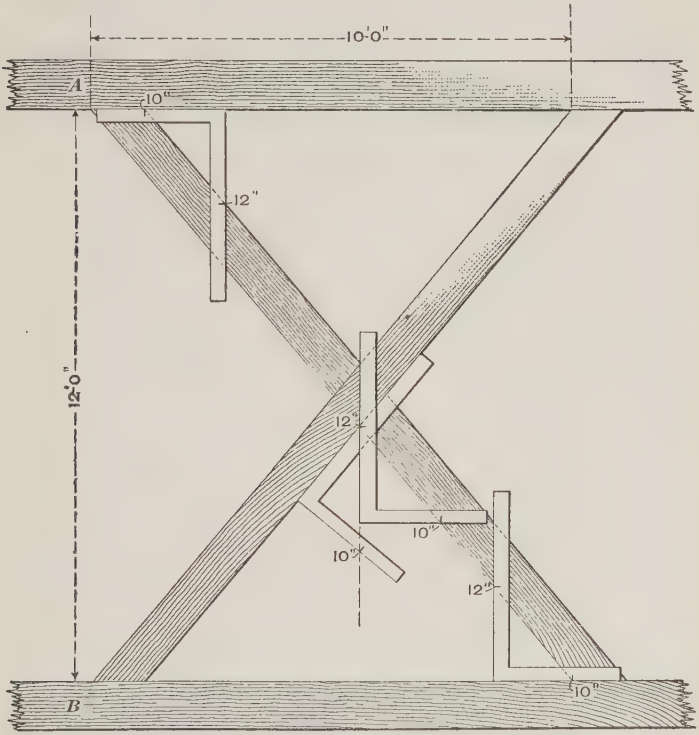

FIG. 20

readily seen that applying the square twelve times will give not only the run and rise, but also the length of each brace. It should be remembered, however, in using the figures on the square, that the 10 inches on the tongue and the 12 inches on the body represent the run and the rise on a scale of 1 inch to 12 inches.

The bridge measure of 10 and 12 inches is 15.62 inches, and $12 \times 15.62 = 187.44$ inches, which is the length of the

brace. If, instead of calling the marks on the body and the tongue inches, they are designated as feet, the bridge measure will be 15.62 feet, and 15.62 feet is equal to 15 feet 7.44 inches, or 187.44 inches. It will be observed that the tongue of the square will give the top and bottom cuts, and the body of the square will give the cut at the center to frame the two braces together.

39. Board Measure.—The number of feet, board measure, may be found by the aid of the square without referring to the board-measure scale. When a number of boards of the same length, but having different widths, are

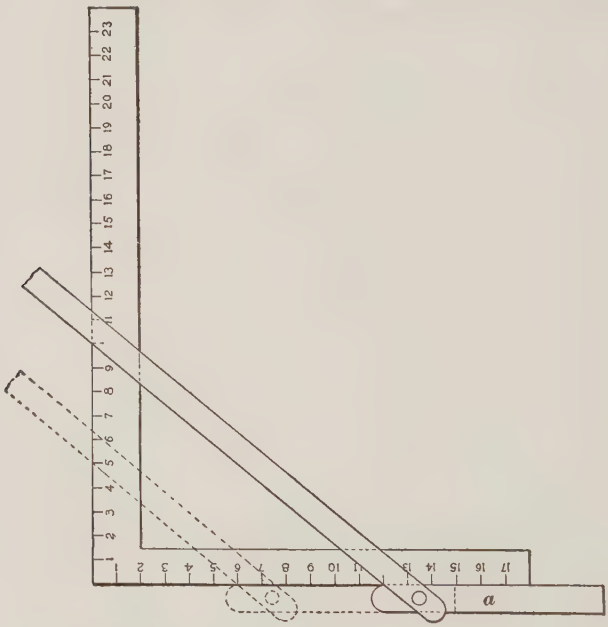

FIG. 21

to be measured, the following method will probably save time, especially if a bevel instrument with a long blade is used.

At *a*, Fig. 21, is shown the application of the bevel to the square. The blade of the bevel is set at the 12-inch mark on the tongue of the square and at the number corresponding

to the length of the board on the body of the square. Then, to find the number of feet, board measure, in the board, move the bevel so that the blade will intersect on the tongue the number equal to the width of the board. The bevel will then indicate on the body of the square the number of feet in the board.

In Fig. 21, the bevel is first set at *12* and *10*, the *10* being the length of the board in feet. The bevel is then moved along the tongue of the square to *6*, which is the width of the board in inches. When in this position the blade of the bevel rests on the body of the square at *5*, which is the contents of the board in square feet.

If the board were 16 feet long, 7 inches wide, and 2 inches thick, the bevel would be set at 12 inches and 16 inches, then moved to 7 inches on the tongue, and the bevel would indicate the contents of a board 1 inch thick, which would be $9\frac{4}{12}$ feet. This quantity must then be multiplied by 2, because the board is 2 inches thick. The product will be $18\frac{8}{12}$ feet, which is the contents of the board.

LAYING OUT POLYGONS

40. Although the steel square is particularly adapted for roof framing and is probably used more for that kind of work than for any other purpose, there are a great many other uses for the instrument. The mechanic that thoroughly understands the principle of the steel square will continually find new problems that can be solved with greater ease by the use of this instrument than by any other method. Therefore, before taking up the subject of roof construction, a few of the uses to which the square may be put will be explained.

41. Classification of Polygons.— A **polygon** is a plane figure bounded by straight lines. The bounding lines are called the **sides,** and the length of the broken line that bounds the figure is called the **perimeter** of the polygon. A **regular polygon** is one in which all the sides and all the angles are equal.

Polygons are classified according to the number of their sides: A polygon of three sides is called a **triangle;** one of four sides, a **quadrilateral;** one of five sides, a **pentagon;** one of six sides, a **hexagon;** one of seven sides, a **heptagon;** one of eight sides, an **octagon;** one of nine sides, a **nonogon;** one of ten sides, a **decagon;** one of eleven sides, an **undecagon;** and one of twelve sides, a **dodecagon.**

42. Laying Out an Equilateral Triangle.—In Fig. 22 is shown a method of finding the angle of the sides and also the miter angle of a regular polygon of three sides. A regular polygon of three sides is an **equilateral triangle,** and

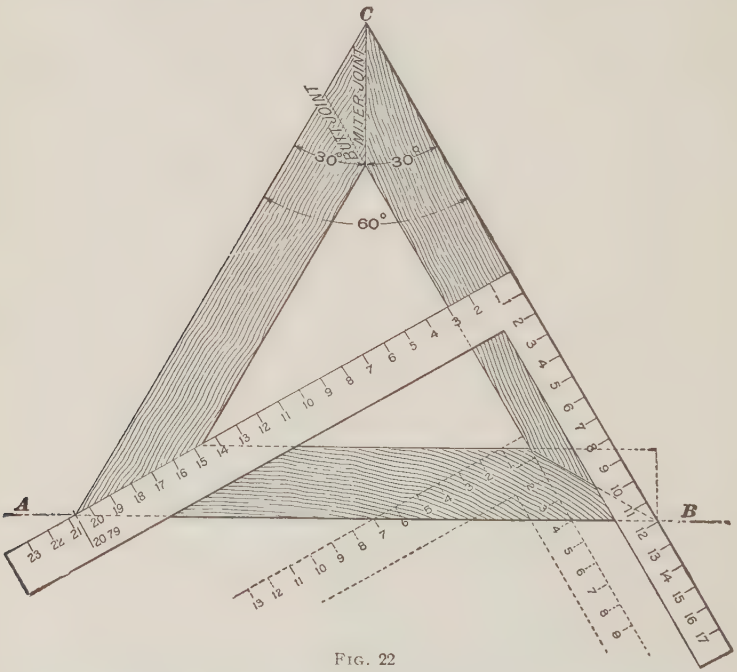

FIG. 22

is consequently **equiangular,** that is, all sides are equal in length and the angles contain the same number of degrees.

In the illustration, *A B* represents the line on which the triangle is to be formed. Place the square so that 12 inches

on the tongue and 20.79 inches on the body are over the line AB; then, the tongue will give the direction of one side of the triangle. By reversing the square so that the 12 inches is at A and the 20.79 inches is at B, the other side of the triangle may be drawn. The intersection of these two lines at C completes the triangle.

43. If a frame is to be constructed, the body of the square will give the direction to cut for a miter joint.

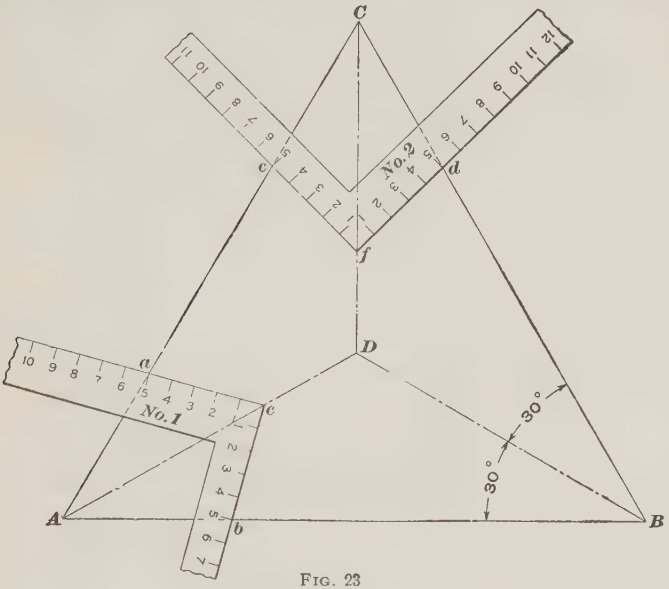

FIG. 23

If a butt joint is required, however, the cut will be along the tongue, using the same figures on the square. The miter joint makes an angle of 30° with the sides, while the butt joint is parallel with the sides. The direction of these cuts can also be found by using 7 inches on the body and 4 inches on the tongue. While these figures are not absolutely correct, they are close enough for all practical purposes. They may be proved by using the proportion 20.79 : 12 = 7 : 4.04. It will therefore be seen that 4 inches is .04, or about $\frac{1}{32}$, inch too short.

44. Locating the Center of a Triangle.—Fig. 23 shows one method of finding the center of a triangle, also a method of bisecting any angle. This same method may be used to find the center of any regular polygon. *A B C* represents the triangle. Make *A a* equal to *A b*, and place the square as shown at *No. 1;* that is, with equal divisions resting on the lines *A C* and *A B*, at *a* and *b*. Make a mark at the heel of the square as at *e*, and from *A* through *e* draw a line of indefinite length. From the angle at *C*, lay off *C c* and *C d* equal to each other. Place the square, as shown, at

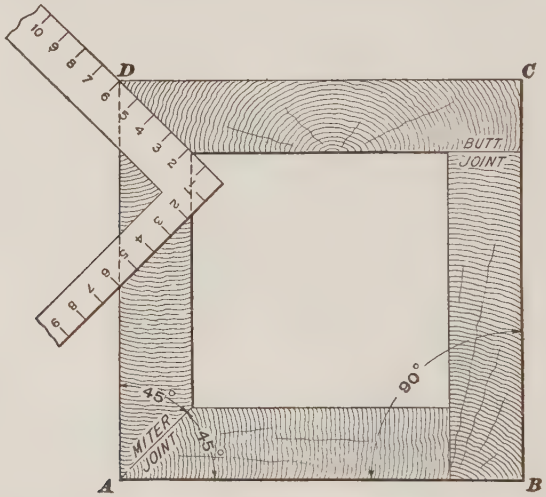

FIG. 24

No. 2, and make a mark at *f*. From *C*, through *f*, draw a line intersecting the other line *A D*; then, *D* will be the center of the triangle. To prove the work, the same operation may be repeated at angle *B*. Then, if the line *B D* intersects the other two lines at *D*, the operations at *A* and *C* have been performed correctly.

The lines *A D*, *B D*, and *C D* bisect the angles *A*, *B*, and *C*, respectively. In the illustration, the 5-inch mark is used on both the body and the tongue of the square. Any other figures may be used, however, provided they are at equal distances from the heel of the square.

45. Laying Out a Regular Quadrilateral Polygon, or Square.—Fig. 24 represents a square frame. The corners at *A* and *D* are made with miter joints, and those at *B* and *C*, with butt joints. The miter joint shown is the true miter, because the pieces are cut off at an angle of 45°. Common usage, however, has made it customary to speak of a miter joint when the pieces come together at angles other than 45°.

In order to find the direction of the cut for a 45° miter joint, use any equal numbers on the body and on the tongue, and cut along either edge of the square. In the illustration, 6 inches and 6 inches have been used. It will be observed that the body coincides with the direction of the miter at *D*, and that the tongue is parallel with the miter at *A*. The butt joint is a square cut.

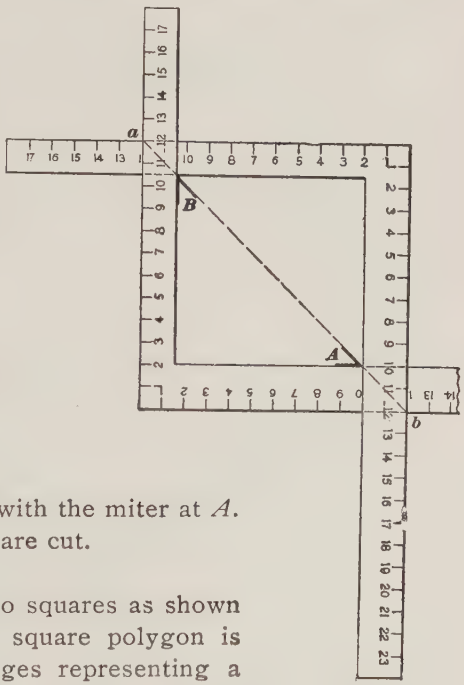

FIG. 25

46. By placing two squares as shown in Fig. 25, a regular square polygon is formed, the outer edges representing a square with 12-inch sides. Now, if a line *a b* is drawn diagonally from 12 inches to 12 inches, on measurement it will be found to be 16.97 inches long, but for most practical purposes, 17 inches will be found sufficiently exact. The constant, 17 inches, plays a very important part in roof framing. By assuming that the 12 divisions on a square represent feet instead of inches, the 17 will also represent feet. Now, assuming that the *12* on the body represents the *run* of a rafter, and that

the *12* on the tongue represents the *rise*, then the 17 will represent the length of the rafter. This operation will also give the cuts of the rafter at the plates and ridge. Bevel *A* will give the correct angle of cut at the plate, and bevel *B* will give the correct cut at the ridge.

47. Laying Out a Regular Pentagon, or Five-Sided Polygon.—In Fig. 26, *A B C D E* represents the outside of a pentagon. To construct the pentagon, draw a line *A b*, and place the square on this line, as shown, with 11 inches on the body and 8 inches on the tongue. Mark along the tongue *A E*; then reverse the position of the square, as shown at *A B b*, and mark along the tongue *A B*. The two sides of the pentagon, or at least the direction of the two sides, will then be determined. To find the direction of the side *B C*, erect a perpendicular to the line *A E* at *4*, or the center of the line *A E*; then place the square as shown by the dotted lines. In the same manner, the direction of the other sides may be found; or, the direction and lengths may be found by the use of compasses.

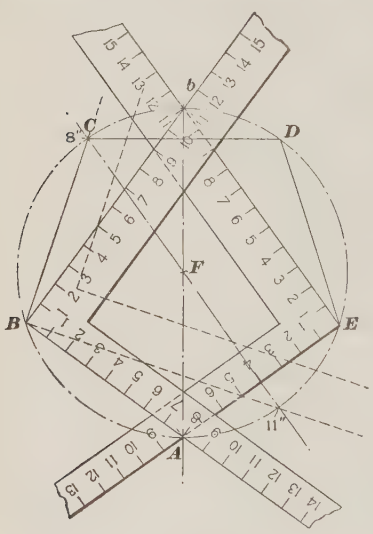

FIG. 26

48. Fig. 27 shows the method of using a square to find the miter and butt joints of a pentagon. The same figures on the square that gave the directions of the sides in Fig. 26, that is, 11 inches and 8 inches, will also give the miter cut, the cut being along the 8-inch side. For the butt joint, take 12 inches and 3.9 inches, and cut on the 3.9 inches side.

49. Laying Out a Regular Hexagon, or Six-Sided Polygon.—The method of finding the direction of the sides of a regular hexagon is the same as that just described for a

pentagon. The figures on a square to use for finding the sides of a hexagon are 12 inches and 6.93 inches, the figure last mentioned giving the direction.

In Fig. 28, *A B C D E F* represents the outline of a hexagon. At *A*, *B*, and *C* are shown miter joints, and at *D*, *E*, and *F*, butt joints. Take 12 inches on the body and 6.93 on the

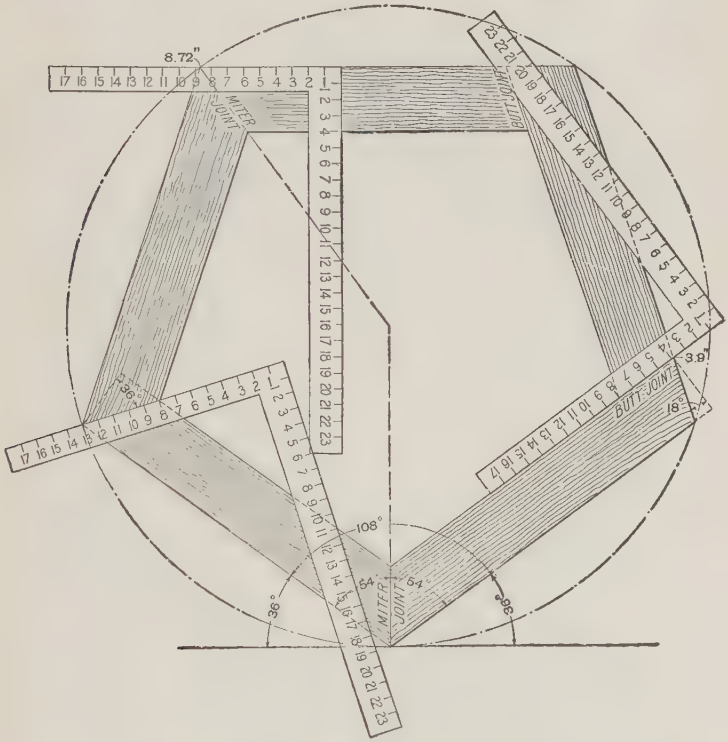

FIG. 27

tongue of the square, and mark along the tongue for both the miter and the butt joints. The whole numbers on the square that will give the hexagon cuts are 7 and 4, and the proportion 12 : 6.93 = 7 : 4.04 will show how nearly correct these figures are. It will be seen from this proportion that if 7 and 4 are used, the 4 is short by .04, or about $\frac{1}{32}$, inch. While this difference is very little for one cut, it should be

remembered that as the number of sides increase, the error is multiplied by twice the number of sides. The polygon in question will have twelve cuts, and the difference for each cut, if 7 and 4 are used, will be 15′, or $\frac{1}{4}°$, and for twelve cuts it will be $12 \times 15' = 180'$, or 3°. Therefore, instead of the sum of the interior angles of the hexagon being equal to 720°,

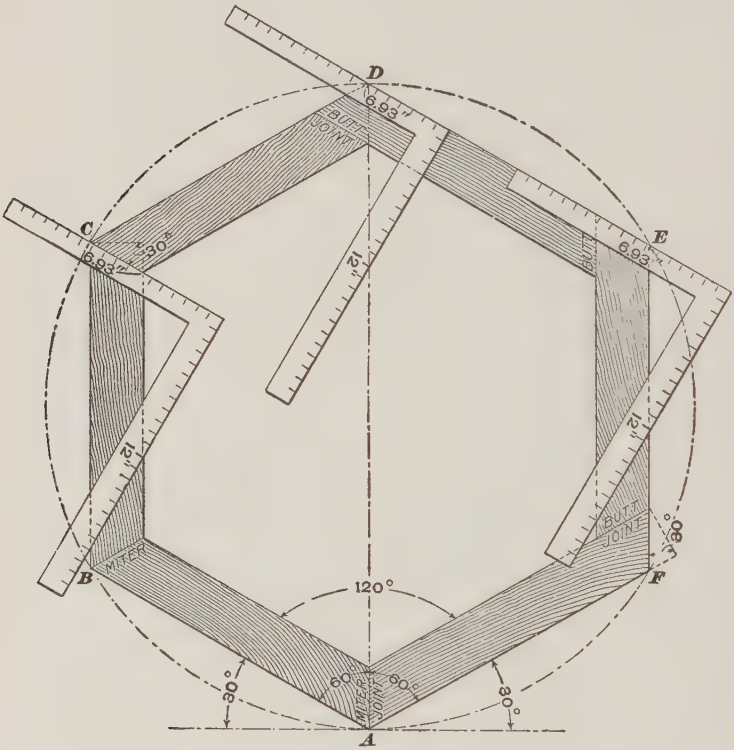

Fig. 28

it will be equal to $720° - 3° = 717°$. Or, again, each angle of the hexagon is equal to $120° - 30'$, or $\frac{1}{2}°$, which is $119\frac{1}{2}°$.

50. Laying Out a Regular Heptagon, or Seven-Sided Polygon.—The same method employed for finding the direction of the sides in a pentagon or hexagon may be used for laying out a heptagon.

In Fig. 29, *A B C D E F G* represents the outside of a regular heptagon. The angles at *A*, *B*, *C*, and *D* are miter joints, and those at *E*, *F*, and *G* are butt joints. The figures on the square that give the cuts for the miter joint are *12* and *5.78*, the cut being on the 5.78-inch side. For the butt joint, take *12* and *9.57*, and the 9.57-inch side gives the cut.

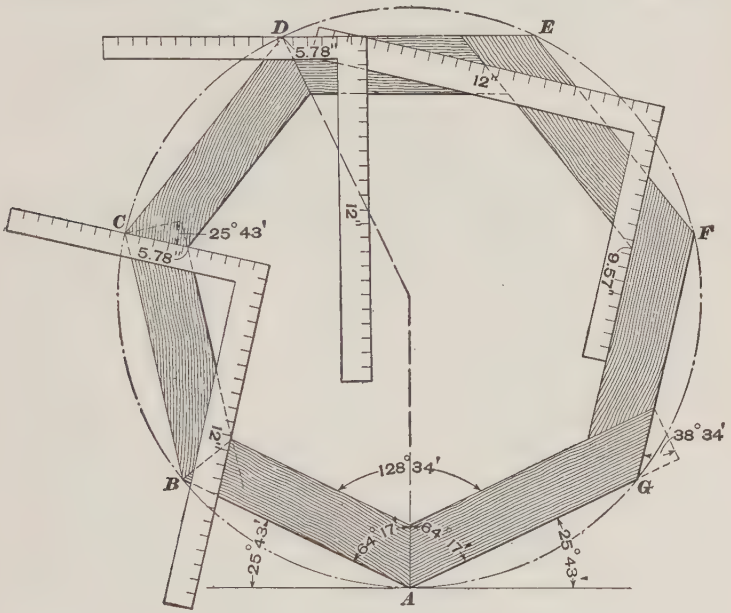

FIG. 29

The figures on the square that give the miter cuts for the heptagon are $14\frac{1}{2}$ and 7. These figures are very close, as will be seen by the proportion 12 : 5.78 = 14.5 : 6.984.

51. Laying Out a Regular Octagon, or Eight-Sided Polygon.—In Fig. 30, *A B C D E F G H* represents the outside lines of an octagon. The figures on the square that give the miter cuts are *12* and *4.97*, the cutting to be done on 4.97-inch side. The figures to use for butt joints are *12* and *12*, or any equal distances from the heel on the tongue and the body of the square. In other words, the cut for a butt joint is a square miter.

The whole numbers that give the octagon miter are *17* and *7*. These figures are very nearly correct, as will be seen by taking 12 and 4.97, which are absolutely correct, and making the proportion 12 : 4.97 = 17 : 7.04. That is, if 17 is used, 7.04 will be correct. The difference in this case is not so great as would be supposed. To find just what the error will be, take the proportion 17 : 7 = 12 : 4.94 and compare it

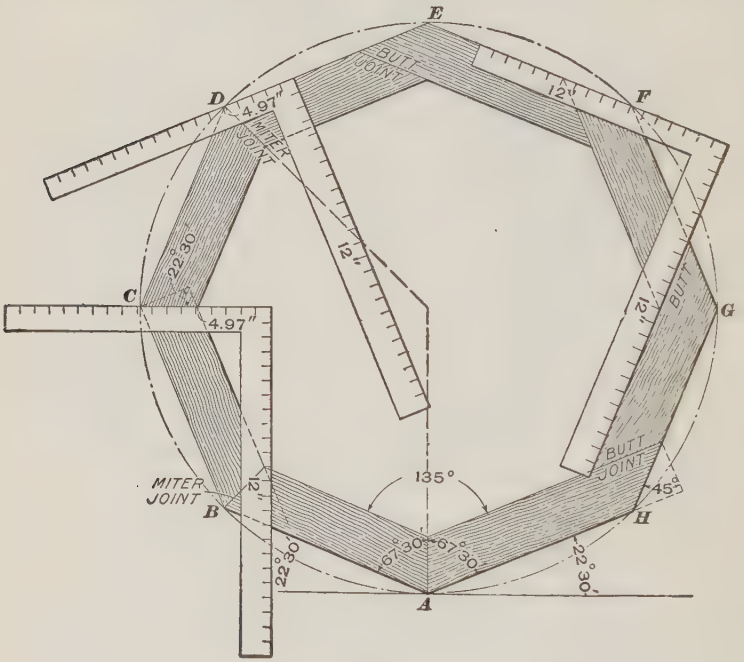

FIG. 30

with the correct figures, which are 12 and 4.97. Thus, the actual error due to using 17 and 7, is .03 inch, which is equal to 6′ in each cut, or 12′ in each joint; and for the eight joints, will be 96′, or 1° 36′. It might be well to mention here that these comparisons are stated in this manner more to show the care that should be taken in cutting to the exact figures, especially in fine work, than to show the relation of the figures on the square to degrees and minutes.

The figures giving the cuts of squares, hexagons, and octagons will be found very useful in roof framing, and should therefore be kept in mind.

52. Marking a Miter-Box. — Fig. 31 illustrates a method of finding the marks on a miter-box so as to cut a strip of molding to fit around a column having the shape of a regular hexagon. By applying the square to the edge of

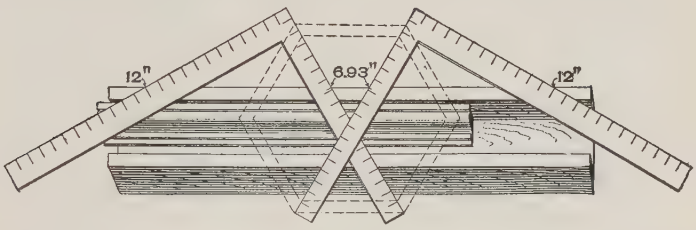

FIG. 31

the box, using the figures *12* and *6.93*, and marking along the 6.93-inch side, the correct miter will be found; then, by reversing the square and using the same figures, the corresponding miter cut will be obtained.

ANGLES OF POLYGONS

53. Table II gives the angles between sides, the miter and butt angles of polygons, and also the exact figures to use on the steel square to obtain the cut for miter and butt joints. The column marked Whole Numbers for Miter gives the nearest whole number to use on the square. These figures are not exactly correct, but are very close.

54. Inscribing a Polygon.—The last column of Table II gives the figures to use in order to find the radius of a circle that will fit around the outside of a regular polygon.

EXAMPLE.—The length of one side of an octagon is 20 inches. What is the radius of a circle that will go around, or circumscribe, the octagon?

SOLUTION.—The figures in the column Radius of Circumscribing Circle and opposite Octagon, under Name of Polygon, are 1.30656.

TABLE II

ANGLES OF POLYGONS

Number of Sides	Name of Polygon	Interior Angle Between Sides	Miter Angle	Butt Angle	Miter and Butt Joints Cut on Body			Whole Numbers for Miter		Radius of Circumscribing Circle = Side Multiplied by
					On Tongue	On Body For Miter	On Body For Butt	Tongue Inches	Body Inches	
3	Triangle	60°	60°	−30°	12	20.78	6.93	4	7	.57735
4	Square	90°	45°		12	12		Any whole number		.70711
5	Pentagon	108°	36°	18°	12	8.72	3.90	11	8	.85065
6	Hexagon	120°	30°	30°	12	6.93	6.93	7	4	1.00000
7	Heptagon	128° 34¼′ +	25°.43′	38.34	12	5.78	9.57	14½	7	1.15238
8	Octagon	135°	22.30	45°	12	4.97	12.00	17	7	1.30656
9	Nonagon	140°	20°	50°	12	4.37	14.30	22½	9	1.46190
10	Decagon	144°	18°	54°	12	3.90	16.52	9½	3	1.61803
11	Dadecagon	147° 16½′ +	16°.22′	57.16	12	3.52	18.67	14	3	1.77473
12	Dodecagon	150	15°	60°	12	3.22	20.78	13	3½	1.93185

Multiplying 20 inches by the quantity thus obtained, the length of radius is 26.13 inches. The diameter of the circle will therefore be $26.13 \times 2 = 52.26$ inches. Ans.

55. Inscribing a Circle in a Polygon.—To find the length of side of a polygon to fit around a circle of known radius, multiply the diameter of the circle by the figures under Miter and Butt Joints, in Table II, using the figures directly under For Miter.

EXAMPLE.—Required, the length of one side of an octagon to fit around a column 18 inches, or 1.5 feet, in diameter.

SOLUTION.—Under the column headed For Miter and opposite Octagon, under Name of Polygon, will be found the value 4.97. This value multiplied by 1.5 feet gives 7.45 inches, which is the length of one side of the octagon that will fit around the column.

ANGLE OF MITER

56. In the preceding articles, figures for obtaining the miter cuts of polygons have been given, but the reason for using these figures has not been stated. Before giving an explanation, however, it might be well to illustrate and explain

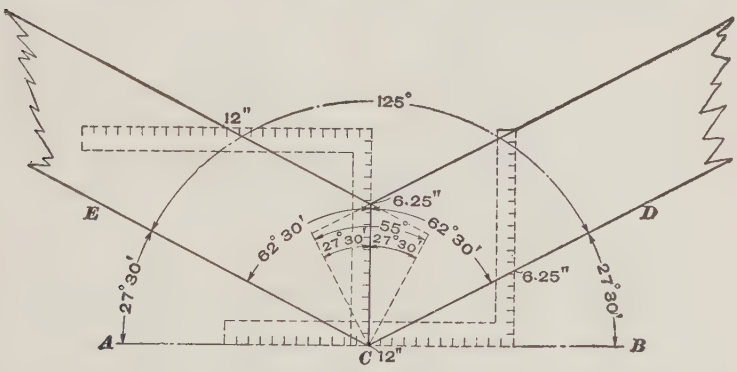

FIG. 32

more fully the **angle of miter.** In Fig. 32 are shown two boards that are mitered together at an angle of 125°. If the boards were joined at an angle of 180°, the cut across them would be square. Now, it is required to find out how many

degrees must be cut off of each board, or, in other words, the miter angle. As the boards in the figure form an interior angle of 125°, it will readily be seen that they are 55° from a straight line, that is, 180° − 125° = 55°. Now, draw the line *A B* at right angles to the line of miter. The line of miter bisects the angle between the boards, and it is quite evident that one-half the difference between 180° and 125° will measure the angle *B C D*, making it equal to 27½°; consequently, *A C E* will be equal to 27½°. Each piece cut off of the boards, provided the boards are square, will therefore be 27½°.

If a plan of the boards were drawn, it would be an easy matter to lay the square on the plan and thus find the figures on the square; but very often it is impossible to have plans of all the work on hand. Furthermore, calculated figures are more accurate than scaled figures.

57. In Fig. 33 is shown the relation of the square to degrees, and how the figures are obtained for forming polygons or mitering pieces at different angles. In the previous article, it was shown that the miter angle for two pieces standing at an angle of 125° was 27½°. By inspecting the semicircle, Fig. 33, it will be seen that the line from *12* on the tongue of the square passing through 27½° on the semicircle passes through the body of the square at 6.25, or 6¼ inches. In other words, the tangent of 27½° is 6.25 inches, so that 12 inches on the tongue and 6.25 inches on the body, cutting along the body of the square, will miter two pieces when the interior angle is 125°, which will readily be seen by referring to Fig. 32.

58. The polygon miters from three to twelve sides are also shown in Fig. 33; likewise, the figures to use on the square are marked on the margin. It will be observed that these figures are derived from the body of the square and are determined by a line drawn from *12* on the tongue to the degree mark corresponding to the miter angle.

A line drawn from 12 on the tongue of a square to the 22½° mark on the circle passes through the body at 4.97 inches.

As $22\frac{1}{2}°$ is the miter angle for an octagon, then the correct figures to use in laying out an octagon are 12 and 4.97 inches. In other words, 4.97 inches is the tangent of $22\frac{1}{2}°$.

59. Fig. 34 shows the construction of an octagon, using the angles as shown in Fig. 33. To find the center of the octagon, draw a perpendicular line from 6 on the body of

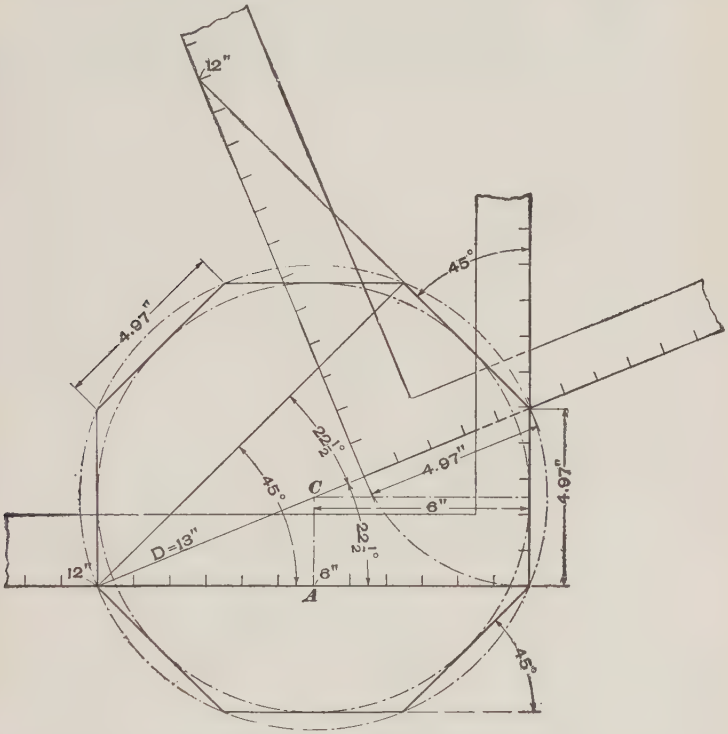

FIG. 34

the square, intersecting the $22\frac{1}{2}°$ line at *C*. This point will also be the center of either an inscribed or a circumscribed circle. It will readily be seen that the line *A C* is half the length of one of the sides. The bridge measure of 12 and 4.97 is the diameter of the circumscribing circle. The diameter of the inscribed circle may be found by dividing the length of the side by the miter. The bridge measure of

12 and 4.97 is 12.988, or, approximately, 13. This figure 13 plays a very important part in octagon construction.

As will be noted, the radius of the inscribed circle is 6 inches; therefore, the diameter is 12 inches, or 1 foot. From the foregoing explanation, the diameter, in feet, of the inscribed circle can be found by dividing 4.97 by 4.97, which is equal to 1.

60. Fig. 35 shows the foregoing principles as applied in the construction of a hexagon. The only difference is in

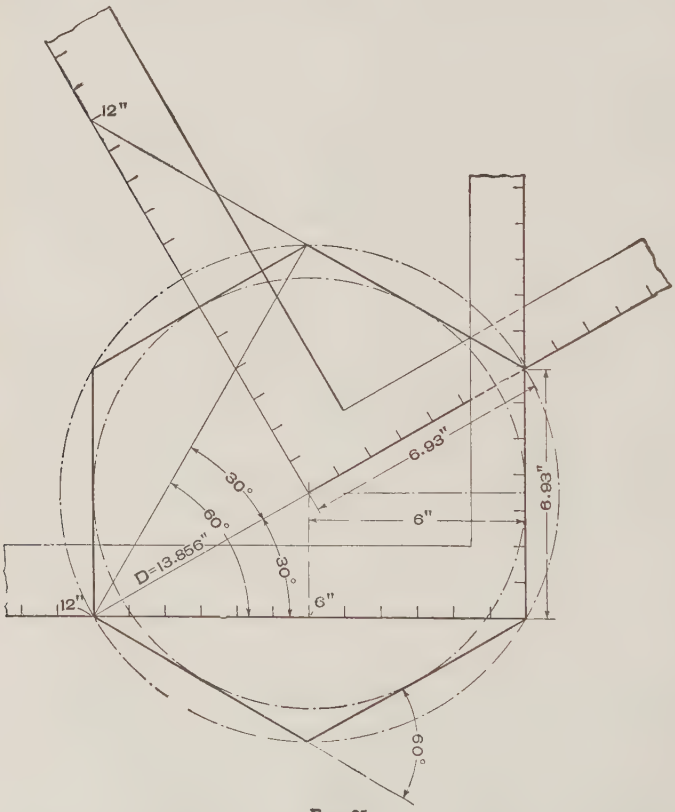

FIG. 35

the angles used; consequently, the bridge measure is different. The radius of the inscribed circle is the same, and is

found in the same way as was explained for finding the radius of a circle inscribed in an octagon. The bridge measure of 12 and 6.93 is 13.856 inches. The foregoing remarks will apply to all regular polygons.

DESCRIBING CURVED OUTLINES

61. To Describe a Circle With the Square.—In order to describe a circle with a square, first drive two pins or nails *c* and *d* on a line *A B*, as shown in Fig. 36, and the

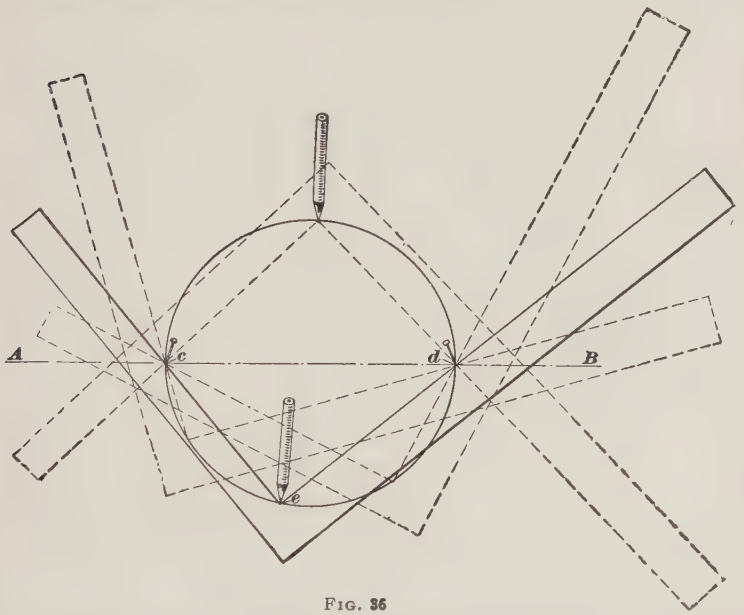

FIG. 36

distance between the points *c* and *d* will be the desired diameter of the circle. Then, with the inner edges of the square pressing against the pins and a pencil point placed as at *e*, revolve the square around the pins, and thus obtain one half of the circumference. Reverse the square for the other half.

This same principle may be applied in testing a block of wood that has been gouged out so as to receive a

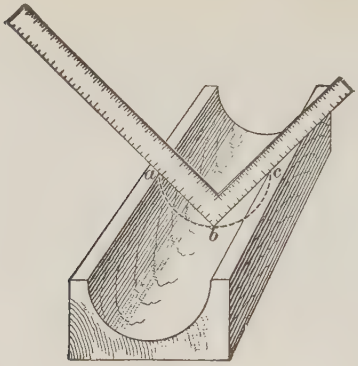

FIG. 37

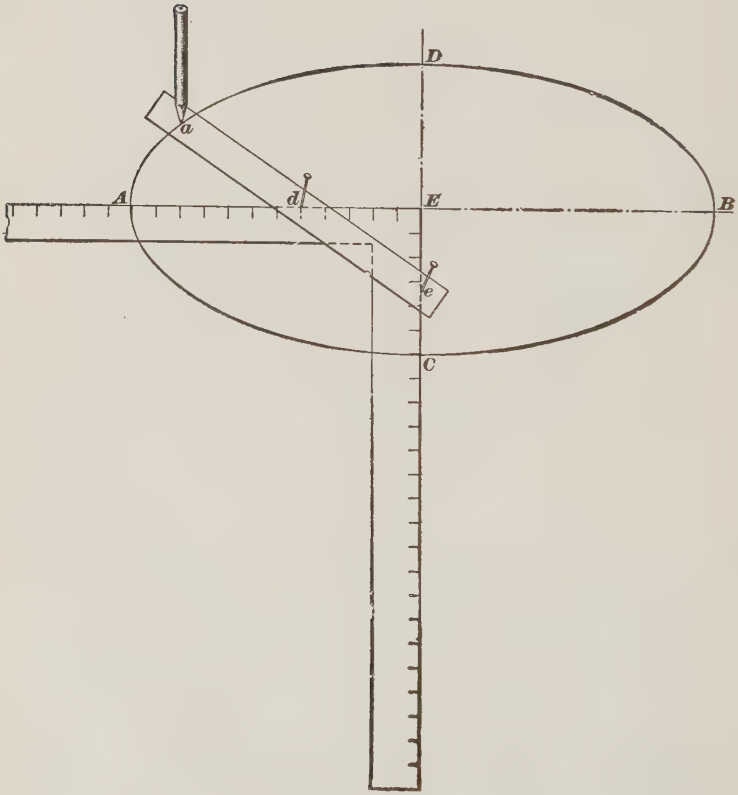

FIG. 38

cylindrical body, such as a core box for a cyclindrical core. To test the work to see that it is true, place a square as shown in Fig. 37. If any part has not been cut out deep enough, the corner *b* will touch that part, and the edges *a* or *c* will not come in contact with the edge of the box. If any part has been cut too deep, the point *b* will not touch that part when the edges of the square rest on the sides of the box. The reason for this is that the angle between two lines drawn from any point on the circumference of a circle to the extremities of the diameter is a right angle.

62. To Describe an Ellipse With the Square.—To describe an ellipse with a square, first draw two lines at right angles to each other, as *AB* and *CD*, Fig. 38. Let *AB* represent the longitudinal axis, and *CD* the transverse axis, both being of the desired length. Place the square so that the heel will rest at the intersection of the axes, as at *E*, and the body and tongue will rest on the transverse and longitudinal axis, respectively. Take a thin strip of wood, and on it lay off $ad = ED =$ half the transverse axis, and $ea = EA =$ half the longitudinal axis. Drive nails into the strip as at *e* and *d*, and make a hole, as at *a*, large enough to admit a pencil point. Now, place the strip as shown, and move the point *a* from *A* to *D* with *e* and *d* always touching the square; then, the point *a* will describe one-fourth of the ellipse. In the same way, by reversing the square, the rest of the ellipse may be drawn.

This method may be used in constructing centers for elliptical arches, and ellipses from a very small size up to 36 in. × 48 in. may thus be made. The method described is on the same principle as the elliptical trammel, the steel square taking the place of the trammel frame.

LAYING OUT VARIOUS PARTS OF A STRUCTURE

63. Laying Out Stairs.—To obtain the figures on a square required to lay out a stringer for a straight stairway, it is first necessary to know the rise and the run, or the distance between floors and the length of space available. In Fig. 39 the distance between floors is 10 feet 6 inches, or 126 inches, and the run is 12 feet 9 inches, or 153 inches. There will be 18 risers. To find the height of each riser,

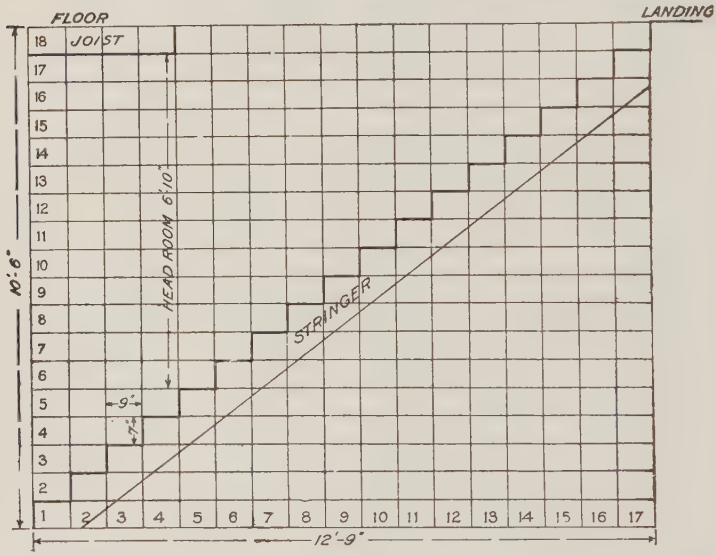

FIG. 39

divide 126 inches by 18, which equals 7 inches. The width of the treads is found by dividing the run, 153 inches, by 17, which equals 9 inches. Then, by taking 7 inches on the body and 9 inches on the tongue, and marking along the body for the riser and along the tongue for the tread, the stringer may be marked out as shown in the illustration. As the floor at the landing makes one of the steps, there is one tread less than there are risers.

64. Laying Out Stair Stringers.—In an open-stair stringer, the risers and stringers are mitered, and although

they stand at an angle of 45° to each other, the miter, owing

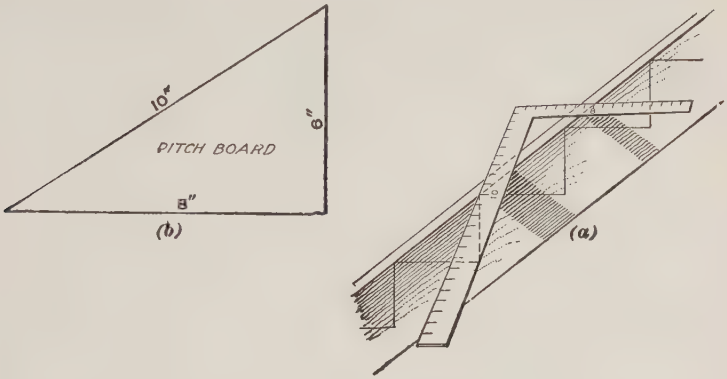

FIG. 40

to the pitch of the stair stringer, is not a square one, but changes with the pitch. In Fig. 40 (*a*) is shown how the cut on the stringer may be obtained by means of the square. The pitch board at (*b*) shows a tread of 8 inches and a rise of 6 inches; the hypotenuse is therefore 10 inches. Take the length of the tread, which in this case is 8 inches, on the tongue of the square, and the length of the hypotenuse, which is 10 inches, on the body of the square, and apply to the stringer as shown at (*a*), marking along the body for the miter cut. The cut on the riser will be a 45° angle.

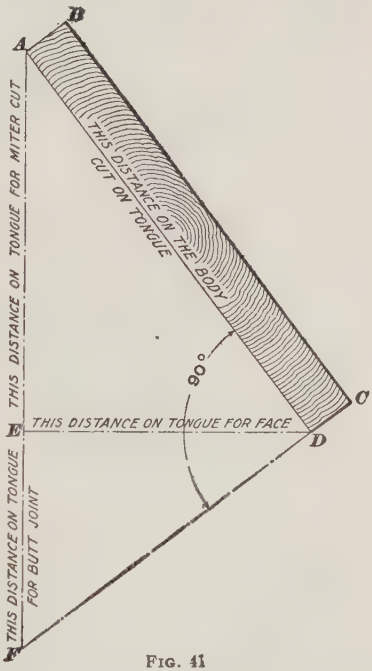

FIG. 41

65. Laying Out Square Hoppers.—A thorough knowledge of how to obtain the several cuts in hoppers will be of great assistance in roof

framing. In Fig. 41 is shown a method of laying out hopper bevels with the steel square. While there are a great many methods for finding the cuts for hopper bevels, the one shown is the simplest and perhaps the easiest to remember.

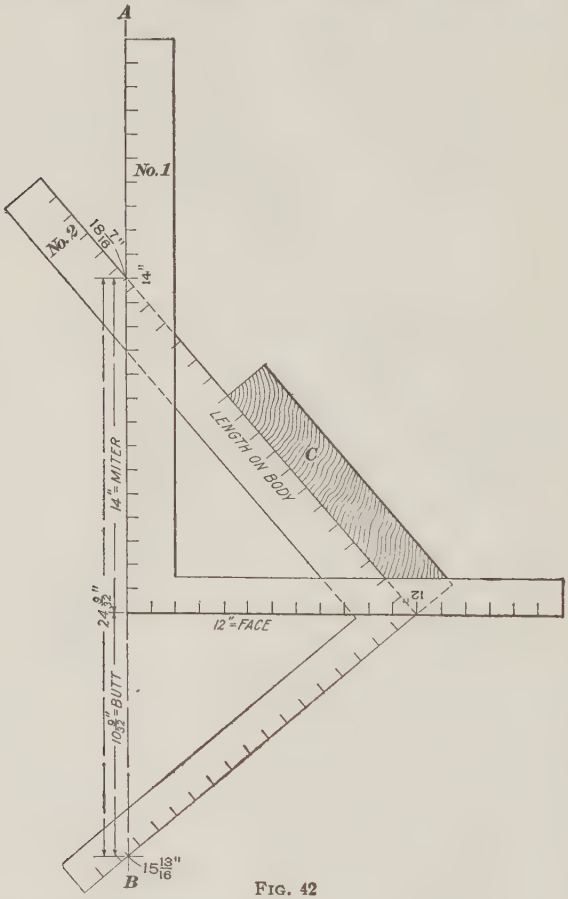

FIG. 42

In the illustration, AF and ED are two lines at right angles to each other; $ABCD$ represents the cross-section of one side of the hopper, and consequently the pitch. From D draw DF at right angles to AD, intersecting the vertical line AF. Then, the distance AD taken on the body of the

square and $A\,E$ taken on the tongue of the square, by cutting along the tongue, will give the cut across the square edge for the miter; $A\,D$ on the body and $E\,D$ on the tongue, cutting along the tongue, will give the cut across the face of the board; $A\,D$ on the body and $E\,F$ on the tongue, cutting along the tongue, will give the cut for the butt joint.

66. It is not necessary to make a drawing in order to get the numbers used on a square to lay out these several cuts. Fig. 42 illustrates the method of using the square. $A\,B$ represents a line, or a straight edge. It is desired to find the several cuts on the plank C in order to make a square hopper, the hopper to pitch 14 inches in 12 inches, or, in other words, the rise is 14 inches and the run is 12 inches. Place square *No. 1*, as shown, along the line, or straight edge, and make a mark at 14 inches on the body; also, scribe along the tongue and make a mark at 12 inches. Next, place the square as shown at *No. 2*, with the heel resting on the mark made at 12 and the body on the mark made at 14. It will be found that the mark on the body of square *No. 2*, where it rests at 14, will be $18\frac{7}{16}$ inches, and that the tongue of square *No. 2* will rest on line $A\,B$ at $15\frac{13}{16}$ inches. Now, take the bridge measure of $18\frac{7}{16}$ and $15\frac{13}{16}$ inches and it will be found to measure $24\frac{9}{32}$ inches. The rise of the hopper is 14 inches in 12 inches; therefore, subtract 14 from $24\frac{9}{32}$

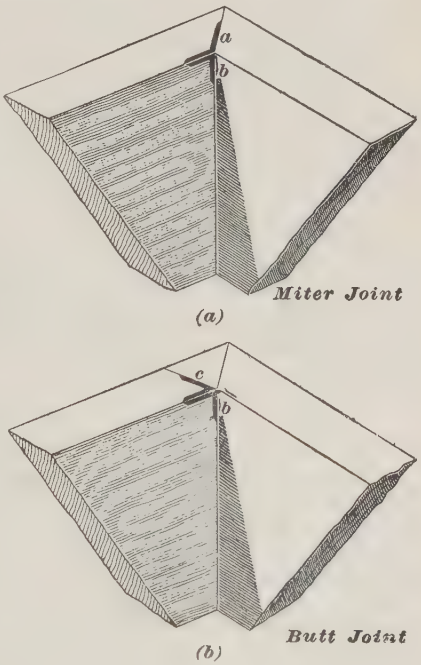

FIG. 43

and $10\frac{9}{32}$ inches will remain. To use these figures, take $18\frac{7}{16}$ inches on the body of the square and 14 inches on the tongue of the square for the miter, $18\frac{7}{16}$ inches on the body and 12 inches on the tongue for the face, and $18\frac{7}{16}$ inches on the body and $10\frac{9}{32}$ inches on the tongue for the butt joint.

67. Fig. 43 shows the several cuts in a hopper. Illustration (*a*) shows the miter joint at *a* and the face cut at *b*,

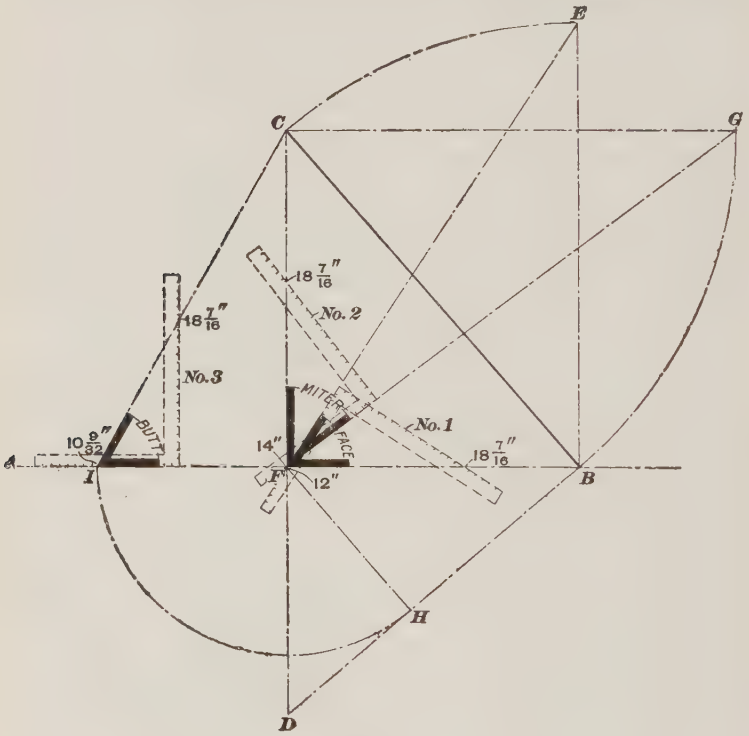

FIG. 44

while in (*b*), *c* shows the butt joint, and *b*, the face cut. The angle for the face cut is the same whether a miter joint or a butt joint is used.

68. In Fig. 44 is presented another method of finding the several cuts for a hopper. Make *A B* and *C D* at right angles to each other; then, draw the line *C B* at the desired

pitch. In this case, the pitch is the same as that shown in Fig. 42. With B as a center and BC as a radius, draw the arc CE, intersecting the line BE drawn at right angles to AB. Connect E with F; then, the angle EFB is the correct angle to cut across the face of the board. Square *No. 1* shows the application.

To find the miter cut on the square edge of the board, take the points C and B in the compasses and describe the arc BG with C as a center. Connect G with F; then, the angle GFC is the correct angle for miter. Square *No. 2* shows the application.

In order to get the butt joint on the square edge, draw the line BD at right angles to CB; then, at some point on the line BD, erect a perpendicular passing through F. With F as a center, and a radius FH, draw the arc HI, intersecting the line AB at I. Connect I and C; then, the angle CIF will be the correct cut for the butt joint. Square *No. 3* shows the application.

69. The principles underlying the solution of hopper cuts are of inestimable value, especially for roof framing and for all splayed work. A hipped corner of a roof is nothing more than an inverted hopper. The bevels found for the face and miter cuts for a hopper are identical with the bevels necessary to cut the face and miter of roof boards that intersect on a hip or in a valley. These bevels are also the same as the bevels required to cut purlins that intersect either against the sides of hips or valleys, or on the back face of same. The same figures on the square would be used for mitering a splayed molding, as for a hopper with equal pitch.

The relation of hoppers to roofs will be taken up in the articles dealing with roof construction.

70. Laying Out an Octagon Bay Window.—A method of laying out an octagon bay window is shown in Fig. 45 (a), where AB represents the line of the building. The sides of the octagon are 40 inches long. To determine the length that will be taken up along the sill, it will be

necessary to know the length from A to E, or the base of the right triangle with a 40-inch hypotenuse. By referring to Fig. 45 (a), it will be seen that the bridge measure, or the hypotenuse, of 12 inches on the tongue and 12 inches on the body is practically 17 inches. Now, by revolving the 12-inch mark on the body to the line of the tongue, produced,

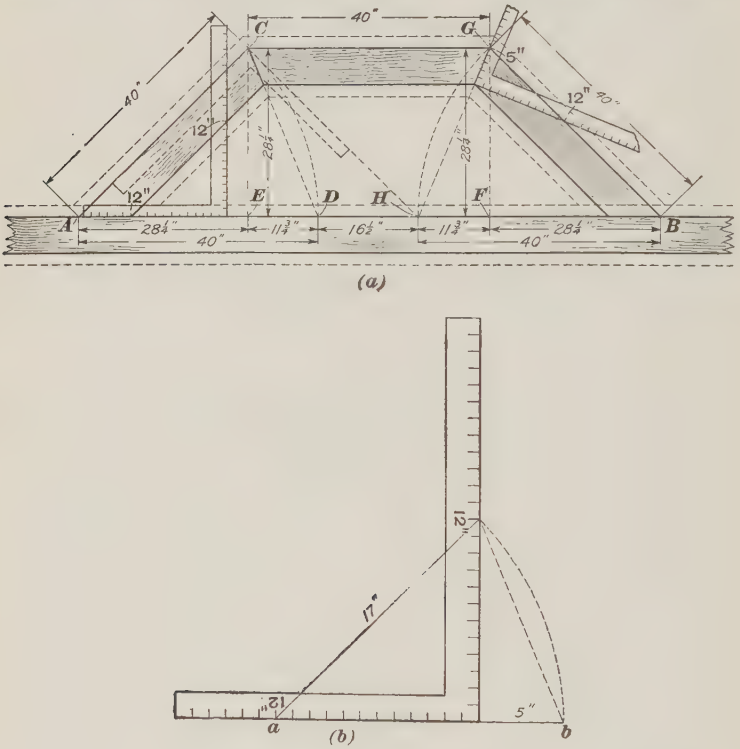

FIG. 45

it will be seen that the line from a to b is 5 inches longer than the 12 inches on the tongue. Then, to find the base, knowing the hypotenuse, multiply the hypotenuse by $\frac{12}{17}$. In Fig. 45 (a), the hypotenuse is 40 inches, and $40 \times \frac{12}{17} = 28.23$, or $28\frac{1}{4}$, inches. The distance, then, from A to E is $28\frac{1}{4}$ inches, and the distance from F to B is also $28\frac{1}{4}$ inches. It is quite evident that the distance from E to F is equal to

CG, and is therefore 40 inches. Thus, the total distance along the sill from A to B is $28\frac{1}{4} + 28\frac{1}{4} + 40 = 96\frac{1}{2}$ inches.

The distance may also be found in the following manner: It is quite evident that the distance AD is equal to 40 inches, and that the distance BH is equal to 40 inches. Now, if the distance DH were known, the length of the sill could be found. The distance AE has already been shown to be $\frac{12}{17}$ of 40, and the distance AD, $\frac{17}{17}$ of 40. Therefore, D is over on EF $\frac{5}{17}$ of 40, and the distance FH is over on EF $\frac{5}{17}$ of 40. Thus, DH is $\frac{7}{17}$ of 40, making DH equal to very nearly $16\frac{1}{2}$ inches.

71. The squares in Fig. 45 (*a*) show the method of getting the cuts in order to fit the sills in place. The dotted line from C to D shows the miter, and by taking $28\frac{1}{4}$ inches on the body of the square and $11\frac{3}{4}$ inches on the tongue of the square, cutting along the tongue will give the miter cut. These are not the figures used on the square in Fig. 45, but they bear the same relation, as will be seen by the proportion $28\frac{1}{4} : 11\frac{3}{4} = 12 : 5$. By referring to Fig. 45 (*b*), the figures *12* and *5* may be verified. If the distance on the house is given, the length of one side of the octagon may be found by dividing the distance by $2\frac{5}{12}$. To find the distance on the house when the side is given, multiply the length of one side by $2\frac{5}{12}$.

72. Miter and Face Cuts for Any Angle and Any Splay.—In Fig. 46 is shown a method of finding the figures on the square that will give the miter and face cuts for two pieces meeting at an angle of 135°, and with a splay, or inclination, of 10 inches in 12 inches from the vertical. In other words, the figure represents one corner of an octagonal hopper. The line AB is the line of miter, in plan, and CD is the inclination of the side.

From the base line EA, erect a perpendicular, drawn to some convenient scale at C, making the line 12 inches long. Then, from the point H, draw the line HI parallel with the base, making this line 10 inches long. Connect C with I, and with C as a center, describe the arc HD; then CD will

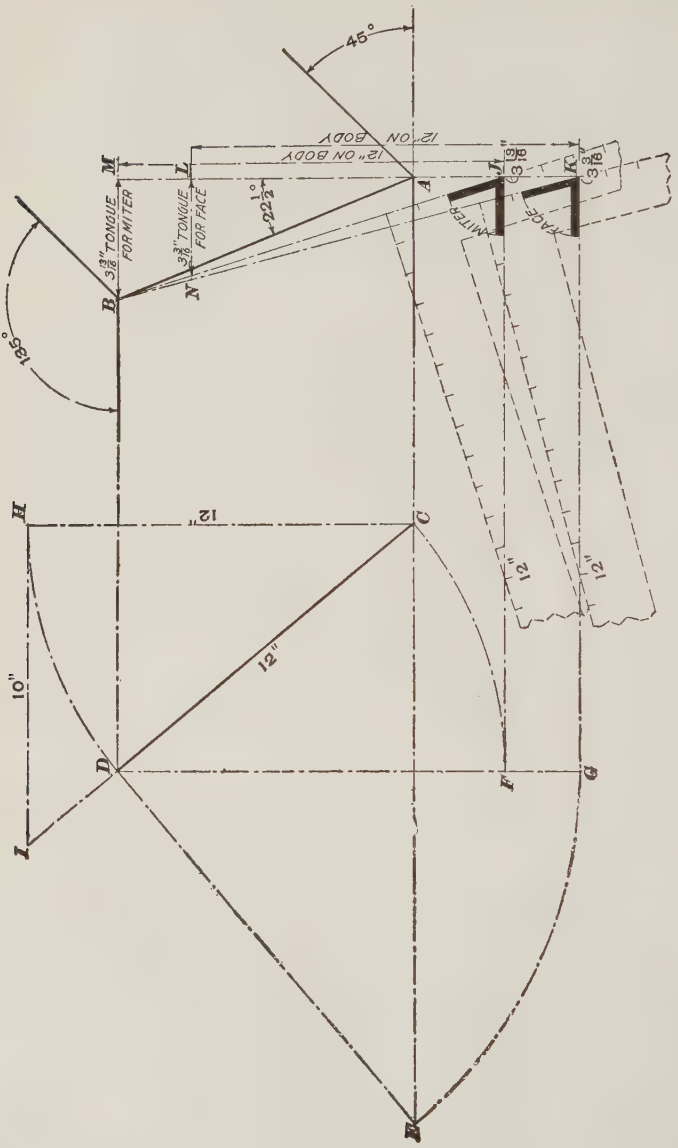
45°
12" ON BODY
12" ON BODY
3/8" TONGUE FOR MITER
3/8" TONGUE FOR FACE
22 1/2°
135°
3/8"
3/8"
MITER
FACE
12"
12"
12"
12"
10"
A
B
C
D
E
F
G
H
I
K
L
M
N

FIG. 46

be the inclination and the correct width of the board. From the point D, let fall a perpendicular to the line EA, producing the line indefinitely below EA. At D, erect a perpendicular to CD, meeting the base line at E. With D as a center, describe the arc EG; also, with the same center, describe the arc CF. At any convenient point on the base line EA, as at A, construct the angle that the two pieces make. In this case, the angle that one side makes with the other side is $180° - 135° = 45°$. From A, bisect the angle of 135°, also erect a perpendicular extending indefinitely on both sides of the line. From D, draw a line parallel with

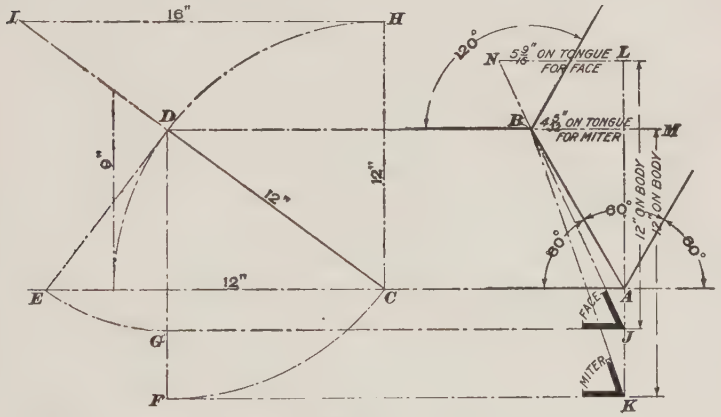

FIG. 47

the base line and intersecting the bisecting line at B; then, AB will be the miter line in the plan. From G and from F, draw lines parallel with the base line and intersecting the vertical line from A at the points K and J, respectively. Connect K and J with B; then, the angle formed at K will be the face angle, and that at J, the miter angle. From K, measure along the vertical line 12 inches to L. At L, erect a perpendicular to the vertical line and measure the distance NL. Then, for the face cut, take 12 inches on the body of the square and $3\frac{3}{16}$ inches on the tongue of the square, and the tongue will give the cut. For the miter cut, measure 12 inches from J along the vertical line to M; also

measure the distance from M to B, which is $3\frac{13}{16}$ inches. Then, take 12 inches on the body of the square and $3\frac{13}{16}$ inches on the tongue of the square, and cut along the tongue. The squares in the illustration show the application.

73. In Fig. 47 is shown the same method as applied to a hexagonal figure. The splay of the side is 16 inches in 12 inches from the vertical, or 9 inches in 12 inches from the horizontal. It will be observed that because the angle from the vertical is more than 45°, the angles for the miter and for the face cuts are the reverse of those shown in Fig. 46. These figures will apply to a square hopper or to any angle.

THE STEEL SQUARE

(PART 2)

Serial 1066B-3 Edition 1

ROOF FRAMING

ROOF MEMBERS

1. The steel square may be used to solve many problems that would be very intricate without its aid; but its greatest usefulness is in roof framing, to which class of work it seems particularly adapted. In treating on the uses of a steel square for roof framing, the several members of a roof will be considered separately, and then examples of complete roofs of both equal and unequal pitch will be given.

As the methods of using the steel square differ in various sections of the country, a diversity of methods will be given, so that a broad knowledge may be obtained of the instrument and of the different ways of using it to obtain the same results.

2. Run, Rise, and Pitch.—The **run** of a rafter is the horizontal distance from the extreme end of the foot, or the outer edge of the plate, to a plumb-line from the ridge.

The **rise** of a rafter is the perpendicular distance from the top of the ridge end of the rafter to the level of the foot, or of the plates.

The **pitch** of a roof is the proportion that the rise bears to the whole width of the building.

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3. Fig. 1 illustrates the terms run, rise, and pitch, and shows the *length* of the rafter. It should be remembered, however, that the term length of rafter does not include

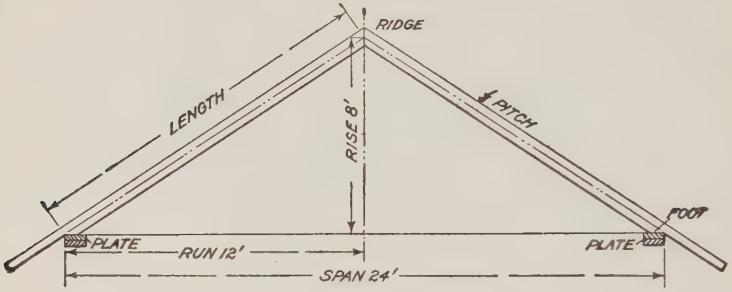

FIG. 1

the projection over the plate. As will be observed, the span of the section of roof shown in the figure is 24 feet and the

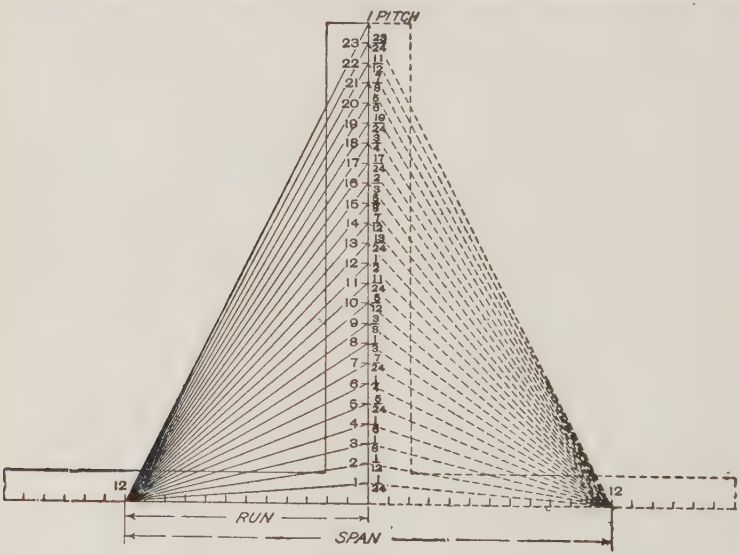

FIG. 2

rise is 8 feet; consequently, the pitch is $\frac{1}{3}$, because 8 is contained in 24, 3 times, or 8 is $\frac{1}{3}$ of 24. If the rise were 12 feet, the roof would be $\frac{1}{2}$ pitch, because 12 is $\frac{1}{2}$ of 24.

4. In Fig. 2 are shown the pitches of roofs having a rise of from 1 inch to 24 inches per foot. By considering the span of a building as 24 inches, the pitch of the roof will be designated as some proportional part of the span. For instance, if the rise is 16 inches in a run of 12 inches, then the pitch will be $\frac{16}{24}$, or $\frac{2}{3}$, as has already been explained. Fig. 2 is introduced at this place in order to more fully illustrate the term *pitch*, as it is very important that the rise per foot should be known even if a certain pitch or total rise is given.

TYPES OF RAFTERS

COMMON RAFTERS

5. Laying Out Common Rafters. In Fig. 3 is shown a plan and elevation of a *shed*, or *lean-to*, *roof*, which is one-half of a saddle roof. This figure also illustrates a method of laying out a common rafter, both the run and the rise of the rafter being 10 feet. As placed in the illustration, the square shows a rise of 12 inches to a foot of run, which is the same as a $\frac{1}{2}$ pitch. The figures to be used on the square, therefore, are 12 inches on the body and 12 inches on the tongue for both the foot- and the plumb-cuts. The length of

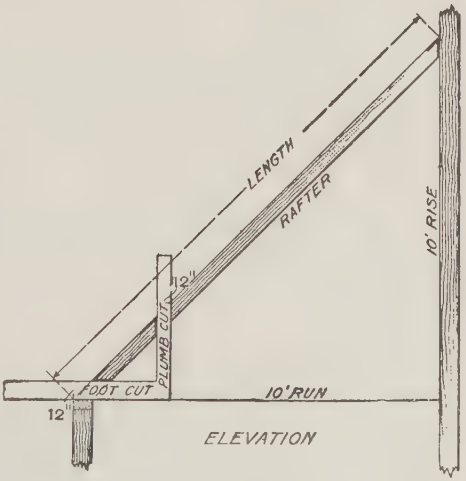

FIG. 3

the rafter can be found by stepping along the rafter timber ten times, because the run is 10 feet.

6. When a portion of a common rafter projects beyond the plate, it can be laid out as shown in Fig. 4, which illustrates a section of a saddle roof having a run of 13 feet and a rise of 6 feet 6 inches. The squares placed at the foot and at the top of the rafter in (*a*) show the figures *12* on the body and *6* on the tongue as the ones to be used to obtain the foot- and the plumb-cuts. As the run is 13 feet, it will be necessary to step along the rafter thirteen times to obtain

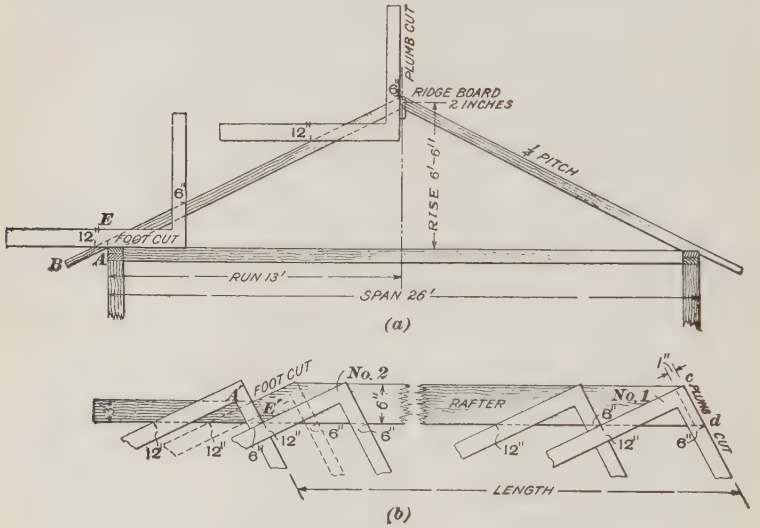

FIG. 4

the length of the rafter. This roof is a $\frac{1}{4}$-pitch roof, the rise being one-quarter of the span of the building. One foot, or 12 inches, is the standard measurement taken on the body of the square to represent the run. For the rise, the figure is determined by the number of inches the roof rises per foot of run. As shown in the figure, the lower end of the rafter projects the distance AB beyond the face line of the wall plate. This distance should therefore be added to the length of the rafter found by stepping thirteen times.

To lay out the rafter, including the projecting portion, proceed as shown in Fig. 4 (*b*). Place square *No. 1* at one end of the rafter timber, with the 12-inch mark on the body and the 6-inch mark on the tongue, even with the top edge of the timber, and then mark along the tongue, as shown at *c d*, for the plumb-cut. Step along the timber thirteen times to *A'*, or to the 12-inch mark on square *No. 2*. Place the square once more, with the same figures, and from *A'* draw the line *A' E'*. Mark a point on this line at the required width of the projecting part of the rafter, as at *E'*, say 3 inches wide; then, place the square at the mark *E'*, as shown by the dotted square, and draw a line for the foot-cut. It will be observed that this mark is at right angles to the tongue of the other squares and that the rafter has been raised the distance *A E* above the plates, as shown in Fig. 4 (*a*).

The rafter is not ready to put in place, however, until a portion of the top equal to one-half the thickness of the ridge board is cut off. If the ridge board is 2 inches thick, measure back 1 inch at right angles to the plumb-cut at the top of the rafter. This cut is shown in (*b*). In practice, instead of making two cuts of the top of the rafter, allowance is made for the ridge board and the necessary thickness removed in one cut.

7. To lay out a common rafter when the run contains a fraction of a foot, resort is had to the method illustrated in Fig. 5, which shows at (*a*) a gable end of a building that is 21 feet 2 inches wide from plate to plate. For a building of this width, the rise and the run of the rafter are each 10 feet 7 inches; consequently, the roof is $\frac{1}{2}$ pitch, because one-half of the span equals the rise. The figures to use on the square for the cuts are 12 inches on the body and 12 inches on the tongue.

To lay out the rafter proceed the same as was done in Fig. 4 (*b*). The distance *a b*, Fig. 5 (*b*), represents the length of the rafter for a 10-foot run. Place the square again from *a*, with 12 inches on the body and 12 inches on the tongue. From the heel of the square, measure 7 inches along the

body to *c*. Slide the square backwards to *d*, and draw the line *de*. It will be noticed that the point *d* is determined by the intersection of a plumb-line drawn from *c*, with a gauge line indicating the thickness of that portion of the rafter which projects beyond the plate. By this operation, it is

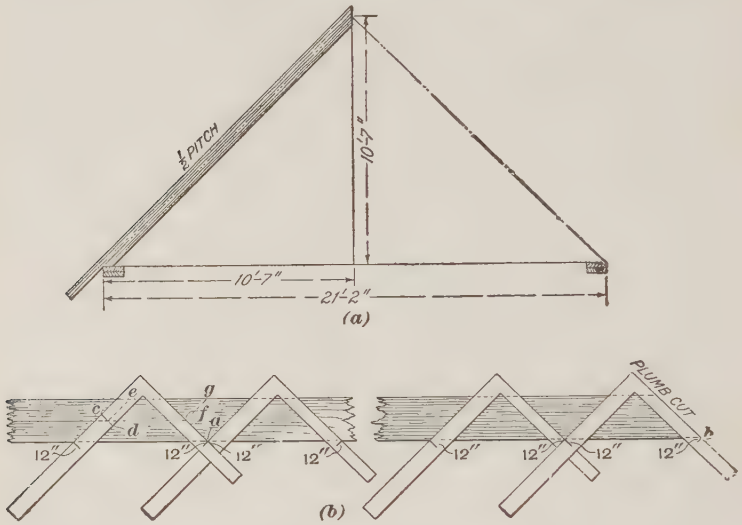

FIG. 5

clearly shown that an addition to the length of the rafter is obtained, and that it is equal to the distance *df*. If the run of the building were 10 feet, the foot-cut of the rafter would be at *fg* instead of *de*.

HIP RAFTERS

8. Laying Out Hip Rafters.—Owing to the fact that a hip is placed diagonally to the plates of a building, and that the pitch is less than the common rafter, the cuts are somewhat different. Fig. 6 (*a*) shows the plan of a true hip roof with a span of 28 feet and a rise of 8 inches per foot of run. The figures to be used on the square to obtain the cuts of the common rafter are 12 inches on the body for the foot-cut and 8 inches on the tongue for the plumb-cut.

The correct length of the common rafter may be found by multiplying the bridge measure, which is $14\frac{7}{16}$ inches, by the run, which is 14 feet. Thus, $14\frac{7}{16} \times 14 = 202$ inches, or 16 feet 10 inches.

To find the cuts for the hips, take 17 inches on the body of the square for the foot-cut and 8 inches on the tongue of the square for the plumb-cut. The length of the hip rafter can be found by taking the bridge measure of 17 inches and 8 inches, which is $18\frac{13}{16}$ inches, and multiplying it by the run

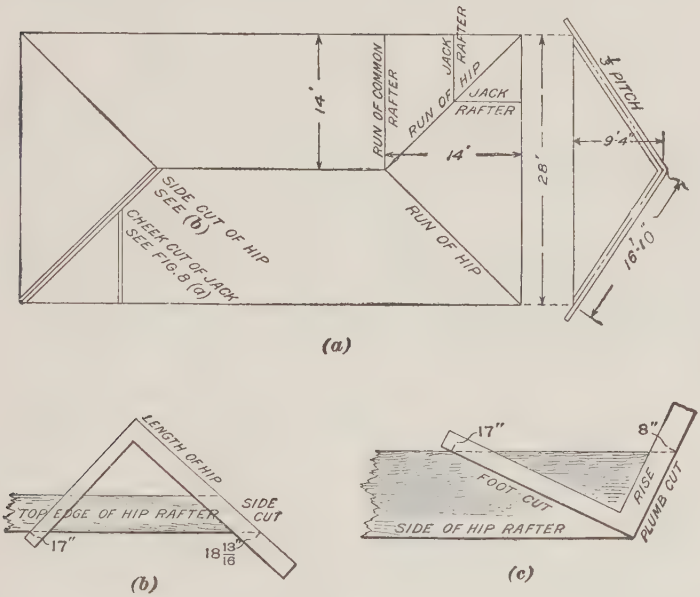

FIG. 6

of the common rafter, which is 14 feet. Thus, $18\frac{13}{16} \times 14$ = approximately 264 inches, or 22 feet.

In any true hip or valley, the figures to use on the square to obtain the foot- and the plumb-cuts, are 17 inches on the body and the rise per foot of the run of the common rafter on the tongue.

9. In order to make the hip or valley rafter fit close to the ridge, another cut besides the plumb-cut is required at

the top. This cut is called the **side cut** of the hip or valley. To obtain the side cut, take 17 inches on the tongue of the square, and the length of the hip per foot run of common rafter on the body of the square, and cut along the body.

In Fig. 6 (*b*), the length of the hip per foot of run is $18\frac{1}{16}$ inches; consequently, by taking 17 inches on the tongue of the square and $18\frac{13}{16}$ on the body of the square and cutting along the body will give the side cut for the hip rafter for a $\frac{1}{3}$-pitch roof. As shown in (*b*), the square is applied to the

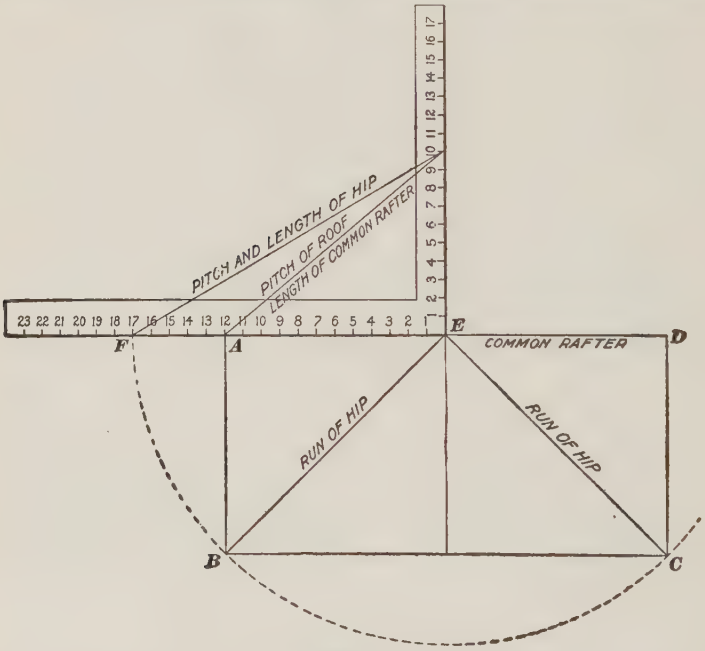
PITCH AND LENGTH OF HIP
PITCH OF ROOF
LENGTH OF COMMON RAFTER
23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
F
A
E
D
COMMON RAFTER
RUN OF HIP
RUN OF HIP
B
C

FIG. 7

top edge of the hip rafter at the figures 17 and $18\frac{13}{16}$ on the square, which are the figures to use for the $\frac{1}{3}$-pitch roof.

10. In (*c*) is shown the application of the square to find the foot- and the plumb-cuts for the hip in a $\frac{1}{3}$-pitch roof. The same figures will also give the cuts for a valley rafter in a $\frac{1}{3}$-pitch roof. The method described here is known as the **17 method.**

The reason for using 17 inches on the body of a steel square when laying out a hip rafter will be made clear by an inspection of Fig. 7. Here, $ABCD$ represents one end of a hip roof 24 inches wide, in which ED is the run of the common rafter, and BE and CE the run of the hip rafter. If the run of hip BE is revolved to the line of the common rafter, the distance EF will be 17, or, to be exact, 16.97 inches. The illustration shows the true pitch of the common rafter, with a run of 12 inches and a rise of 10 inches, and the true pitch of the hip rafter corresponding to this pitch.

JACK-RAFTERS

11. Laying Out Jack-Rafters.—The foot- and the plumb-cuts of jack-rafters are the same as those for common rafters. Jack-rafters differ from common rafters, however, in that a side, or cheek, cut is required at the top of a jack-rafter, in order to make it fit against the hip or valley rafter. In order to obtain this cut, take the run of the common rafter on the tongue of the square and the length on the body of the square and cut along the body.

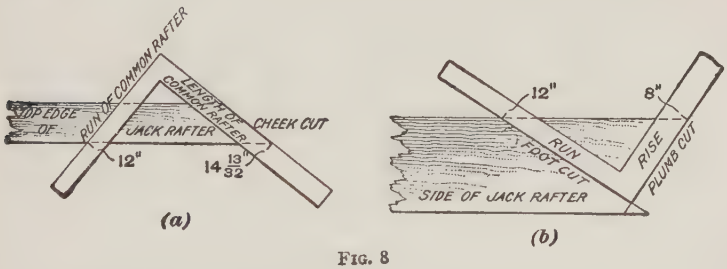

FIG. 8

In a $\frac{1}{8}$-pitch roof, the run is 12 inches, and the length of the common rafter per foot of run is $14\frac{7}{16}$ inches; consequently, by taking 12 inches on the tongue and $14\frac{7}{16}$ inches on the body and cutting along the body, the cheek cut will be found.

In Fig. 8 (*a*) is shown the application of the square at the top edge of a jack-rafter to obtain this cut, while in (*b*) is shown the square applied to the side of the jack-rafter, in order to get the foot- and the plumb-cuts.

12. To find the difference in the lengths of jack-rafters, multiply the length, in inches, of the common rafter per foot of run by the distance, in feet, between centers; subtract this product from the length of the common rafter, and it will give the length of the first jack-rafter or the one next to the common rafter. This same difference subtracted from the first jack-rafter will give the length of the second jack-rafter.

If, on a $\frac{1}{3}$-pitch roof, the jack-rafters are spaced on 2-foot centers, multiply the length of the common rafter per foot of run by 2; thus, $14\frac{7}{16} \times 2 = 28\frac{7}{8}$ inches, or 2 feet $4\frac{7}{8}$ inches, which is the difference in length for all jack-rafters on a $\frac{1}{3}$-pitch roof, where the rafters are spaced 2 feet apart from center to center.

The length of the common rafter in Fig. 6 (*a*) is 16 feet 10 inches. Then, by subtracting 2 feet $4\frac{7}{8}$ inches from the length of the common rafters, the length of the first jack-rafter will be obtained; thus, 16 feet 10 inches $-$ 2 feet $4\frac{7}{8}$ inches $=$ 14 feet $5\frac{1}{8}$ inches. Or, if the jack-rafters are started from the bottom of the hip, the first one will be 2 feet $4\frac{7}{8}$ inches long; the next, 2 feet $4\frac{7}{8}$ inches $+$ 2 feet $4\frac{7}{8}$ inches $=$ 4 feet $9\frac{3}{4}$ inches long; and each one thereafter will increase 2 feet $4\frac{7}{8}$ inches in length for each 2 feet they are spaced. If the jack-rafters are spaced 16 inches on centers, multiply the length of the common rafter per foot of run by $1\frac{1}{3}$ feet, or, expressed decimally, 1.333 feet. This method applies to any pitch.

To find the length of a roof timber multiply the bridge measure per foot of run by the run of the common rafter.

METHODS OF FRAMING

13. Reducing Run and Rise to Inches.—Fig. 9 represents a plan and elevation of a hipped roof of equal pitch, having a run of 15 feet and a rise of 9 feet. To find the figures on the square to obtain the foot- and the plumb-cuts of the common rafter, the run and the rise are first reduced to inches. Thus, the run will be $15 \times 12 = 180$ inches, and the rise will be $9 \times 12 = 108$ inches. As these

figures are beyond the limits of the square, it will be necessary to reduce them, which is done by dividing each number by the same divisor. Assuming 12 for the divisor, $180 \div 12 = 15$ for the run, and $108 \div 12 = 9$ for the rise. By taking *15* on the body of the square and *9* on the tongue of the square and cutting along the body, the foot-cut will be obtained, and by cutting along the tongue the plumb-cut will be obtained.

14. To obtain the length of the rafter, it will be necessary to step twelve times along the rafter timber, or to multiply the bridge measure of 15 and 9 by 12. The rule is to step as many times as the number used for the divisor. Any figure may be used for a divisor, provided it will reduce the run and the rise to figures within the limits of the square.

If 9 is chosen as the divisor, $180 \div 9 = 20$ and $108 \div 9 = 12$, thus obtaining 20 inches for the run and 12 inches for the rise. The *20* on the body of the square gives the foot-cut and the *12* on the tongue gives the plumb-cut. To get the length of the rafter, multiply the bridge measure of 20 and 12 by 9, as 9 was the divisor.

15. Hip- and Valley-Rafter Cuts.—The cuts and lengths of hip rafters and valley rafters are found by the operation just described. For a roof of equal pitch, the plan lines of the hip or valley are in a known proportion to the plan lines of the common rafter. This proportion may be expressed by a rule as follows:

Rule.—*The run of the common rafter is to the run of the hip or the valley rafter as 12 is to 17; that is, for every foot of run of the common rafter, the hip or the valley rafter will be 17 inches.*

Thus, the plan lines of the hips in Fig. 9 will measure 21 feet 3 inches. To find the foot- and the plumb-cuts of the hip rafter, reduce the 21 feet 3 inches to inches, which equals 255 inches. The rise of 9 feet is equal to 108 inches. Reducing these figures to the limits of the square by dividing by 12, gives a run of $21\frac{1}{4}$ and a rise of 9 inches; then, $21\frac{1}{4}$ inches on the body of the square will give the

foot-cut and 9 inches on the tongue will give the plumb-cut. To obtain the length of the hip rafter, step along the timber twelve times, or multiply the bridge measure of $21\frac{1}{4}$ and 9 by 12.

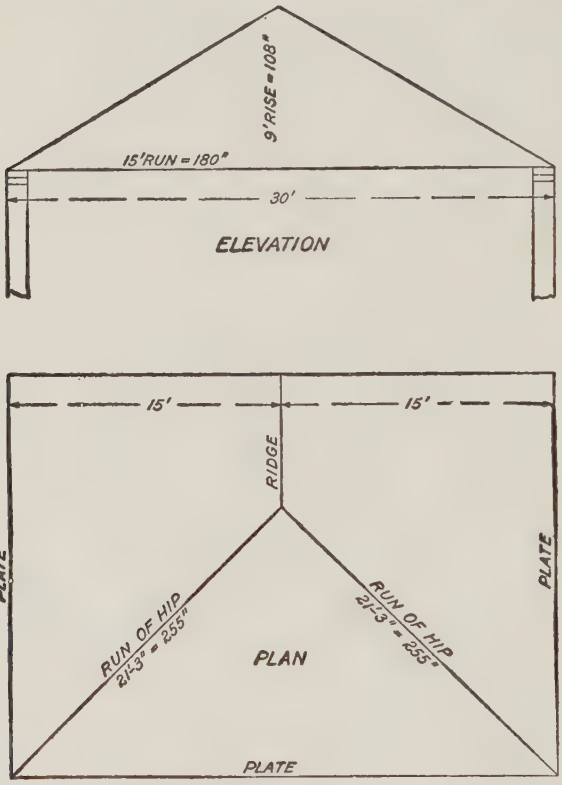

FIG. 9

16. Five-Inch Method.—The **5-inch method** of laying out rafter timbers is applicable to the common and jack rafters of $\frac{1}{2}$-pitch roofs. With this method, the lengths of these roof members may be found by adding 5 inches to each foot of run, as scaled from the plan lines. Fig. 10 shows the plan of a roof with three gables and two valleys, the pitch of the common rafters being 12 inches rise for each foot of run, or a $\frac{1}{2}$ pitch. The plan lines of the common rafters are 12 feet; consequently,

by adding 5 inches twelve times to the run of the common rafter, the length of this rafter will be found. Thus, $5 \times 12 = 60$ inches, or 5 feet, and $12 + 5 = 17$ feet, which is the length of the rafter.

To find the cuts, take *12* on the body and *12* on the tongue, and apply the square to each end of the rafter.

The length of a hip or a valley cannot be calculated by adding 5 inches to each foot of its run. In such cases $2\frac{2}{3}$ inches instead

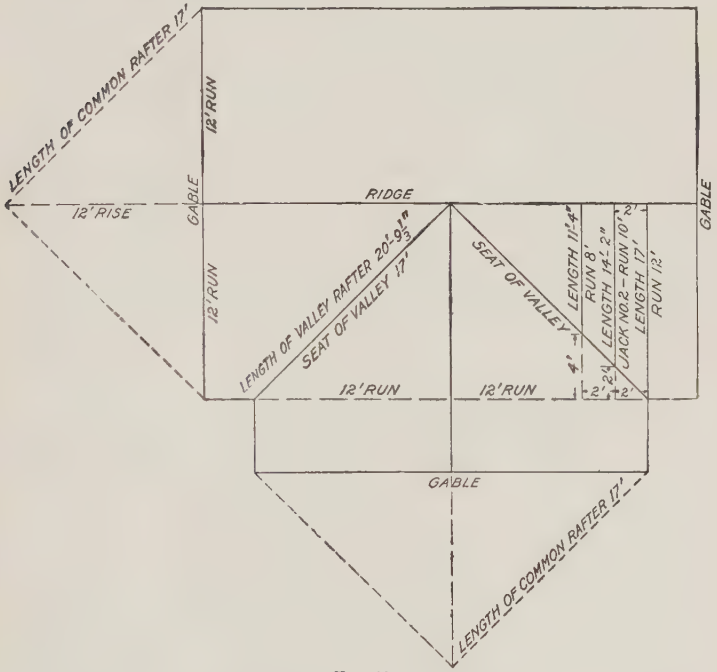

FIG. 10

of 5 inches must be added to each foot of run. Thus, in Fig. 10, the run of the valley is 17 feet. Then, the length of the valley will be 17 feet + 17 × $2\frac{2}{3}$ in. = 17 feet + 3 feet $9\frac{1}{3}$ inches = 20 feet $9\frac{1}{3}$ inches.

17. The length of all the jack-rafters may be determined by the 5-inch method. The jack-rafters in Fig. 10 are

placed 2 feet from center to center; consequently, jack-rafter *No. 2* is 2 feet shorter in plan than the common rafter, thus making the run of this jack-rafter 10 feet. Now, by adding 5 inches for each foot of run, the length of the jack-rafter will be obtained. Thus, $10 \times 5 = 50$ inches, or 4 feet 2 inches; adding this distance to the run of the jack-rafter gives 14 feet 2 inches, which is therefore the length of jack-rafter *No. 2*. The length of the next jack-rafter will be 2 feet 10 inches shorter, or 11 feet 4 inches.

18. Roof Framing From Plan Lines.—Fig. 11 illustrates the plan lines of a hip-and-valley roof of equal pitch,

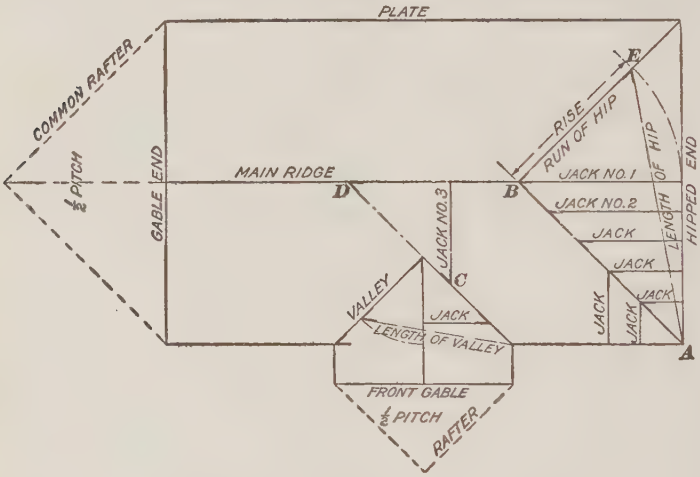

FIG. 11

these lines showing the foot- and the plumb-cuts and the lengths of all the rafters. The method of framing from plan lines can be applied only to roofs of $\frac{1}{2}$ pitch, but as this pitch is probably used more extensively than any other, a knowledge of the method may prove of value. The plan of the roof is usually drawn to a large scale, $1\frac{1}{2}$ inches to the foot making a convenient scale, as each $\frac{1}{8}$ inch on the scale will equal 1 inch on the roof.

19. In Fig. 11 are shown two hips on the right side of the building, while on the left are shown two rafters of the

wide gable. The length of these rafters is equal to the plan lines of the hips. The dotted lines on the left are an elevation of the common rafters, and, as will be observed, these lines and the angles they make with each other are the same as the plan lines of the hipped end; therefore, the construction of an elevation is not necessary.

The length of the common rafter may be found by scaling the plan lines of the hips; or, in other words, the run of the hip is equal to the length of the common rafter. The same is true of the rafters and plan lines of the valleys in the front gable.

20. The similarity of lengths and of angles between common rafters and hip rafters or between common rafters and valley rafters is the fundamental principle underlying the method of framing from plan lines. As the run of the hip has the same length as the common rafter, it is quite evident that the angle that jack-rafter *No. 1*, Fig. 11, forms with the run of the hip will be the plumb-cut, and the angle that the run of the hip makes with the end plates will be the foot-cut.

The angles of jack-rafters, where they intersect hip rafters or valley rafters, are equal to 45°, and by taking 12 inches on both the body and the tongue of the square, the plumb- and the foot-cuts can be obtained.

The jack-rafters may also be laid out on this same principle. Space the jack-rafters as shown—jack *No. 1*, jack *No. 2*, etc. By scaling the plan line of the hip from *A* to *B*, the length of jack-rafter *No. 1* will be found. This jack-rafter is equal in length to the common rafter, and the plumb- and the foot-cuts are the same as for the common rafter.

By scaling the plan line of the hip from *A* to the end of jack-rafter *No. 2*, the length of the latter can be found. The same process of scaling the plan line of the hip will give the exact length of all the other jack-rafters.

The plan line of jack-rafter *No. 3* is shown at *C*. To lay out this rafter, continue the plan line of the valley until it intersects the main ridge; then *CD* will be the length of jack-rafter *No. 3*.

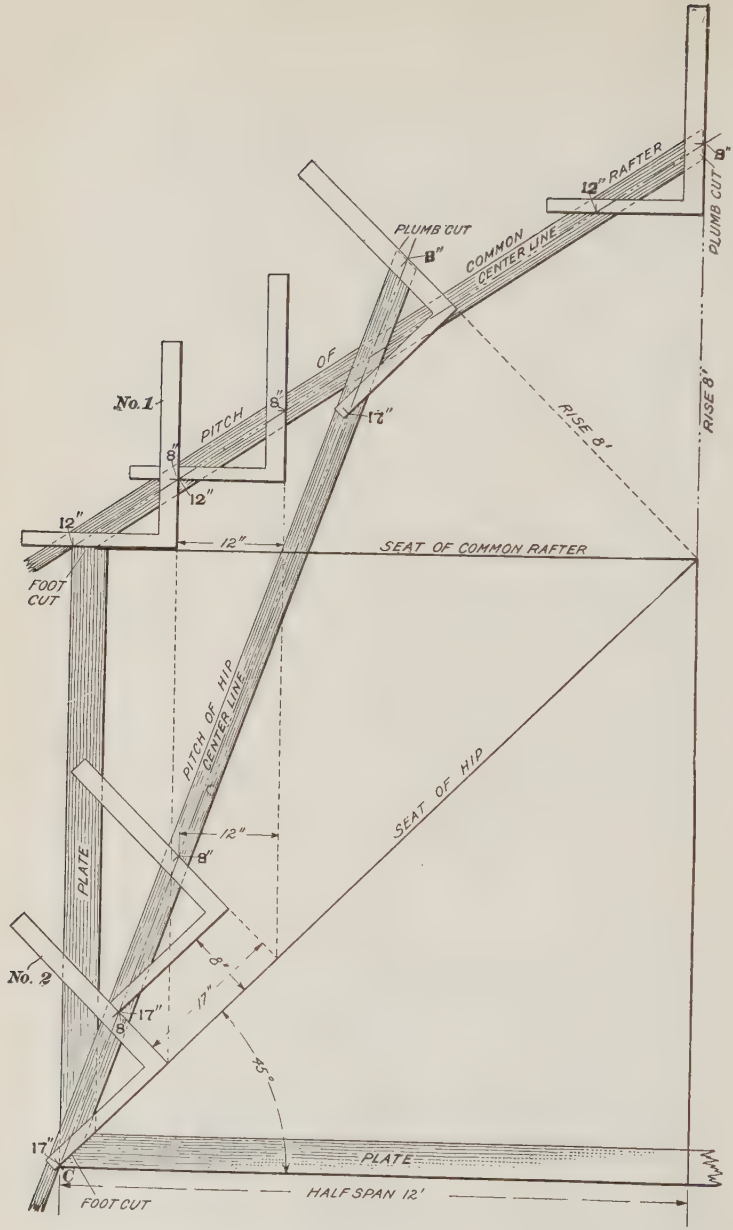
12" RAFTER
8"
PLUMB CUT
PLUMB CUT
8"
COMMON CENTER LINE
No. 1
PITCH OF
8"
17"
RISE 8'
RISE 8'
8"
12"
12"
12"
SEAT OF COMMON RAFTER
FOOT CUT
PITCH OF HIP CENTER LINE
SEAT OF HIP
12"
8"
PLATE
No. 2
8"
17"
8"
17"
45°
17"
PLATE
HALF SPAN 12'
FOOT CUT

Fig. 12

21. To lay out the hip, the plan line of jack-rafter *No. 1* is revolved to *E*, a point on the plan line of the hip. *E* is then connected with *A*, and *EA* is the length of the hip rafter. *BE* is equal to the rise, or the distance that the main ridge is above the plates.

The same process is shown applied to the valley of the front gable. The angles that these lines form with the plan lines of the two hips and the two valleys define the foot- and the plumb-cuts. The figures to be used on the square to lay out the cuts for the hips and valleys, are *12* on the tongue and *17* on the body, the tongue giving the plumb-cut and the body the foot-cut.

22. To Lay Out a Hip or Valley for Equal-Pitch Roofs.—In roofs of equal pitch, the seat of the hip or the valley stands at an angle of 45° with the plates of the building, as shown in Fig. 12. In this figure, the run of rafter is 12 feet, while the rise is 8 feet, thus making the roof $\frac{1}{3}$ pitch. The figures to be used on the square to get the plumb- and foot-cuts are *12* on the tongue and *8* on the body, as shown by the application of square *No. 1* to the pitch of the rafter. By drawing a vertical line from the heel of square *No. 1* to intersect the seat of the hip, and placing the heel of square *No. 2* at the point of intersection, it will be found that *17* on the tongue will come to the corner *C* of the building, thus showing that a 12-inch run on the common rafter is equal to a 17-inch run on the hip or valley.

Square *No. 1* shows a 12-inch run to an 8-inch rise for the common rafter, and square *No. 2* shows a 17-inch run to an 8-inch rise for the hip. The figures *17* and *8* are to be used on the square when laying out the hip rafter or valley rafter, as the case may be. It should be remembered, however, that these figures apply only to hips and valleys on equal pitch roofs. In all roofs of this description and of any pitch, provided the pitches are equal, *17* on the tongue of the square and the rise per foot of run of common rafter on the body of the square will be the figures to use for the foot- and plumb-cuts. For the length of the rafter, it will be necessary to step along

the timber the same number of times as for the common rafter.

23. Jack-Rafters and Roof Boards for a Hip or Valley Roof.—In Fig. 13, $ABCD$ represents the plan of one end of a hipped roof. AE and BE are the seats of the hip; DE and EC, the runs of the common rafters; EF, the rise of the roof; and DF, the length of the common rafter. Erect a perpendicular to the seat of the hip at E, and revolve

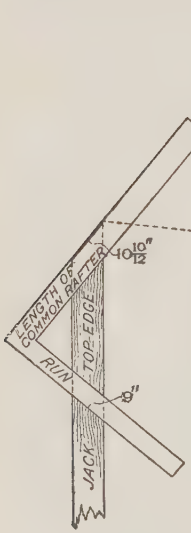

FIG. 14

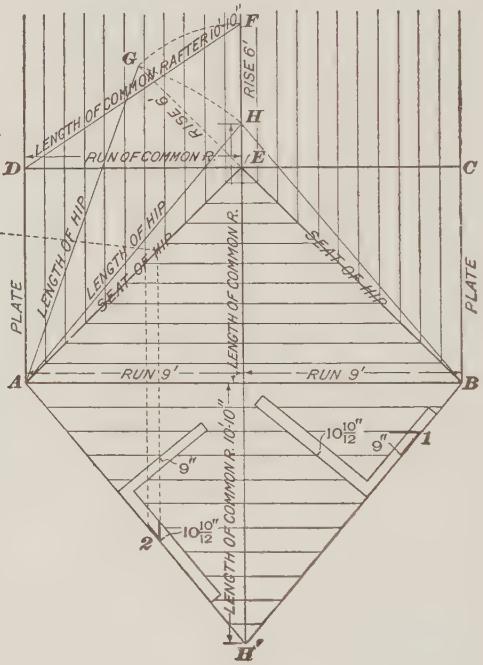

FIG. 13

F to G; or, in other words, make EG the same length as EF. Connect A and G; then, AG will represent the length of the hip. Next, make AH and BH equal to AG; then, the triangle AHB will be the true size and shape of the end roof. Or, assuming that the triangle AEB is hinged at AB and that the point E is revolved so that the triangle AEB will lie flat, or in a horizontal position, then the point E will drop

to H; again, if the roof is revolved in an opposite direction, the point E will revolve to H', and triangles AHB and $AH'B$ will be equal in every respect.

The roof in the position $AH'B$ shows the true lengths and true angles, and, consequently, when in this position, the square or bevel can be laid on any piece and the true angle taken. Thus, the bevels at *1* and *2* are the true angles that the roof boards and jack-rafters make at the hips.

24. In any right triangle in which the true lengths of all the sides are shown, the figures to use on the square to cut any piece to fit the sides or angles may be obtained by taking the length of two of the sides, provided that the piece is parallel with one of the sides. Thus, for the side cut of the jack-rafter, one side of the triangle is 9 feet and the other is 10 feet 10 inches, the former being the run and the latter the length of the common rafter. Then, by taking 9 feet on the tongue and 10 feet 10 inches on the body, and cutting along the body of the square, the side cut of the jack-rafter will be obtained. In order to get these figures within the limits of the square, it is necessary to reduce the figures by dividing each side by the same number. In this case, the divisor will be 12, which is the same as calling the feet inches. Then, take 9 inches on the tongue of the square and $10\frac{1}{2}$ inches on the body of the square, and cut along the body.

From the foregoing explanation, the following rule for the side, or cheek, cut of jack-rafters is deduced:

Rule.—*To find the cheek cut for jack-rafters, take 12 inches on the tongue of the square, and the length of common rafter per foot of run on body of the square and cut along the body.*

25. Fig. 14 illustrates the application of the square to the top edge of a jack-rafter. The plumb-cut of the jack-rafter will be the same as the plumb-cut for the common rafter.

26. On account of the roof boards being at right angles to the jack-rafters, the face cut will be the same as the cheek cut of the jack-rafters, except that the cut is made along the

tongue of the square. Fig. 15 (*a*) shows the square applied to the face of the board while (*b*) shows the figures to use if the roof board is to be mitered so as to make a tight joint at hip or valley.

27. Purlins and Roof Boards.—In Fig. 16 (*a*) is shown part of the plan of a hipped roof with purlins and roof boards in place. Above the plan is shown the elevation of the common rafters, and a section of the purlin and a roof board. In (*b*) is shown a method of obtaining the face cut and miter cut for either the purlins or the roof boards.

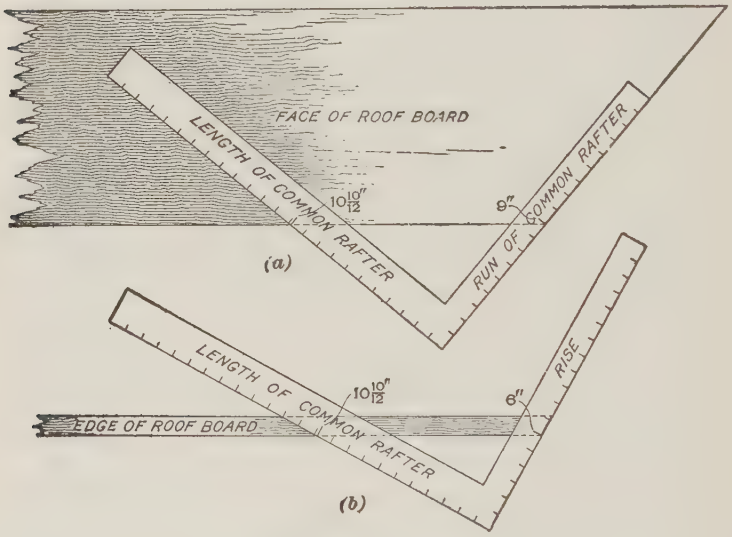

FIG. 15

The line AC represents the length and pitch of the common rafters; AB, the run of the common rafters; and BC, the rise of the roof. Take A as a center and the run AB as a radius, and describe the arc DBE, cutting the rafter line in D and the line AF (which is drawn at right angles to AC through A) in E. Connect CE and FD, and the angle at D will be the miter angle for either the purlin or the roof board, and the angle at E will be the face angle.

It will be observed that the results are the same as were obtained in Fig. 13, the roof having the same pitch. This method is limited to equal-pitch roofs, but not to any special pitch. If a 45° pitch had been illustrated, the miter and face bevel angles would have been equal.

This method may also be applied to hoppers or any other work where the jambs and heads are splayed, such as doors, windows, etc.

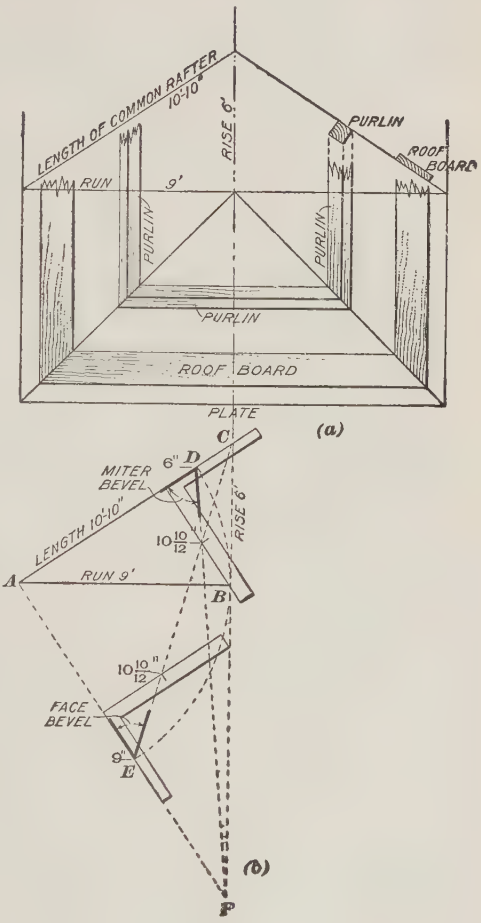

FIG. 16

28. Seat Cut for Hip or Valley.—The following method may be used to lay out the seat cut of a hip rafter or a valley rafter so that the top edge of the rafter—backed or not backed—will be in the same planes as the intersecting roofs. As the hip or valley is placed diagonally to the plates of the building, and the pitch is different than the pitch of the common rafter, there will be a difference in the foot-cuts. At *a*, Fig. 17, is shown the plan lines of a hip or valley intersecting the plates of one corner of a building. In this illustration are also shown the pitch of the common rafter, the hip rafter, and the valley

rafter. It will be noted that the common rafter has a $\frac{1}{2}$ pitch, and that the figures on the square for this pitch are *12* and *12*, while the figures for the corresponding hip and valley rafters are *17* and *12*.

29. Fig. 17 also illustrates the method of determining the thickness of the hip or the valley rafter above the plate, to correspond with the thickness of the common rafter. If a hip is to be laid out, its plan lines will intersect the plates at *M* and *N*, while a valley will intersect the plates at *O* and *P*.

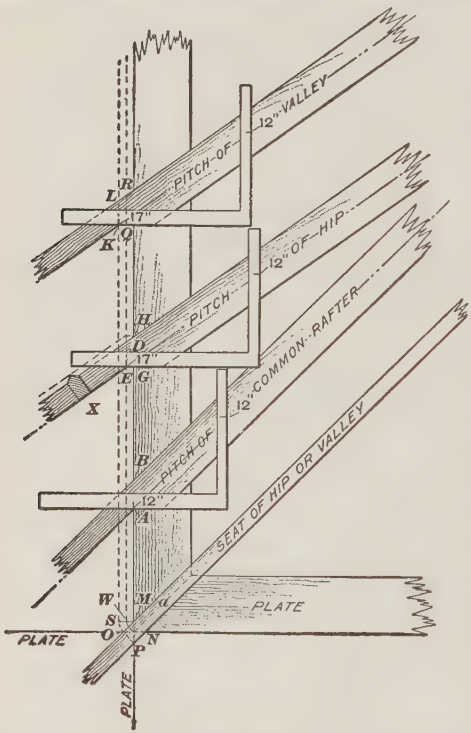

FIG. 17

Lay off *M W* and *W S* equal to one-half the thickness of the hip or the valley timber. Through *W* and *S* draw lines parallel with the plates. Let *A B* represent the thickness of the common rafter above the plates; then, the problem is to find the relative thickness of the hip or valley. For a hip, it will be noticed that the same thickness as that of a common rafter will do, if the hip is not backed, as shown at *G H*, but the foot-cut must be extended to the line *W*, as shown at *E D*. If it is backed, *E D* represents the thickness.

The thickness of the valley is shown at *Q R*, and is the same as that of the common rafter, backed or not backed, but the foot-cut must be extended to *K L*. A rafter is

backed when the upper corners are dressed off to the center of the rafter on either side, so that the top edge will be in the same plane as the roof on both sides of the rafter. The backing of a hip rafter is shown in section at *X* in the illustration.

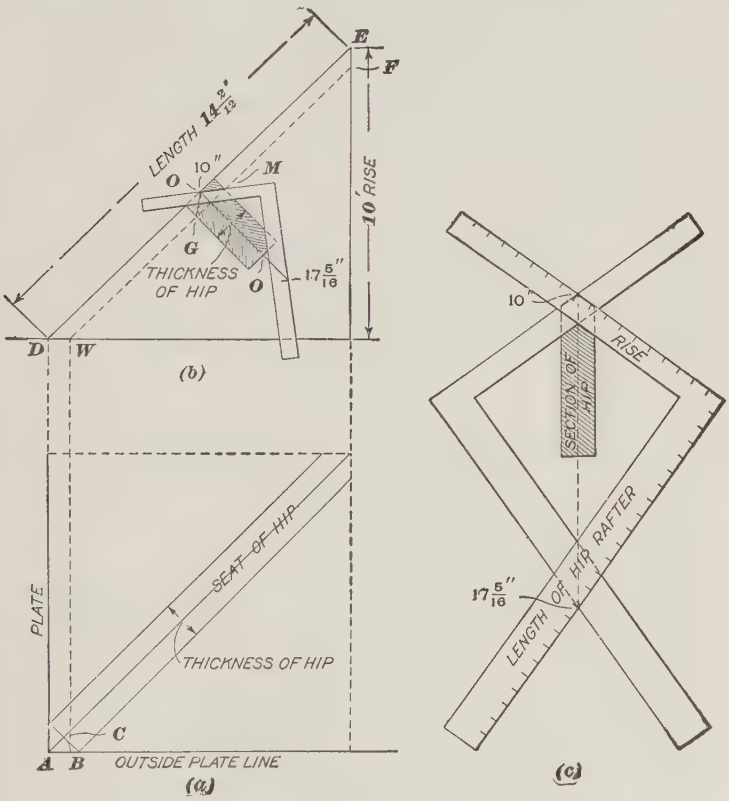

FIG. 18

30. Backing Hip or Valley Rafters.—The following method explains how to find the figures on a square to back a hip or a valley rafter. In Fig. 18 (*a*) is shown the plan lines of one corner of a hip roof, while in (*b*) is shown the elevation of the common rafter, *DE* being the pitch of the rafter. Revolve the point *C* to *B*, which makes *AB*

equal to one-half the thickness of the hip. Through B, draw the line $B\,W$ parallel with the plate, and from W draw a line $W\,F$ parallel with the pitch of the rafter. At any point on the rafter draw a section of the hip at right angles to the rafter. Through the center of the section, draw the line $O\,O$; connect O and G, and O and M; then, $O\,G$ and $O\,M$ will define the backing. The triangular pieces above the lines $O\,G$ and $O\,M$ are to be removed from the hip rafter. The figures to use on the square to obtain the cuts are the length of the rafter on the body of the square and the rise of the rafter on the tongue of the square. The cut will be along the tongue.

In (*b*) the square is shown applied to the rafter timber, and in (*c*) the square is shown applied to both sides of the hip rafter. If a bevel instrument is used, the bevel may be set on the square, clamped to hold its position, and the angle then transferred to the hip timber.

EXAMPLES OF ROOF FRAMING

FRAMING AN EQUAL-PITCH ROOF

31. A complete plan of a hip-and-valley roof of equal pitch is shown in Fig. 19. This is a representative plan of the better class of roofs for a residence, and contains a variety of rafters, hips, valleys, and jack-rafters. The width of the front gable is 16 feet; that of the left-side gable, 12 feet 6 inches; and that of the rear gable, 10 feet. The span of the main roof is 22 feet.

The front gable rafters rise 8 feet and have a run of 8 feet, which is a rise of 12 inches per foot of run. For the foot- and the plumb-cuts, take 12 inches on the tongue for the run and 12 inches on the body for the rise. The tongue gives the foot-cut, and the body, the plumb-cut. For the length of the rafter, step eight times along the rafter timber. If the ridge pole is 1 inch thick, $\frac{1}{2}$ inch is to be cut from the length obtained by stepping. The length as now found will reach

from the plumb-face of the plate to the plumb-face of the ridge pole.

32. To lay out the foot-cut proceed as shown in Fig. 20. Point *A* in this illustration represents the length as found by stepping eight times along the rafter timber from the ridge point, and is therefore plumb above the face of the wall

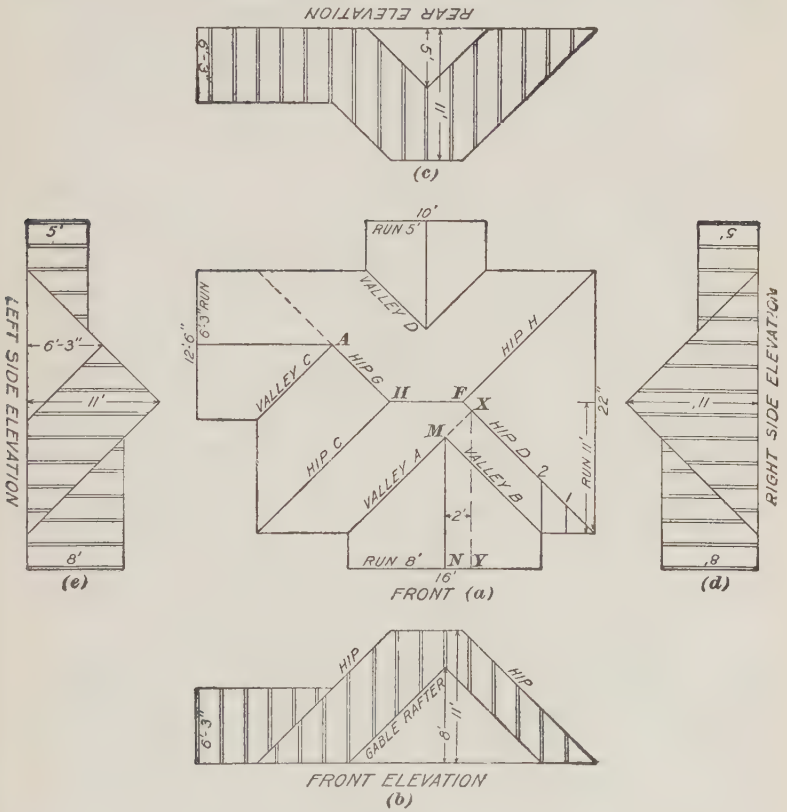

FIG. 19

plate. Place the square with 12 inches on the tongue and 12 inches on the body, as shown by square *No. 1.* From the upper side of the rafter, shown at *A B*, gauge the line *C D* at a distance equal to the thickness of the projecting part of the rafter, designed to support the cornice, beyond the

wall plate. The line CD will intersect the tongue of square *No. 1* at C. Place the square at this point, as shown by square *No. 2*, and draw the line CE, which will be the foot-cut of the rafter.

This completes the laying out of the rafter. The remain-

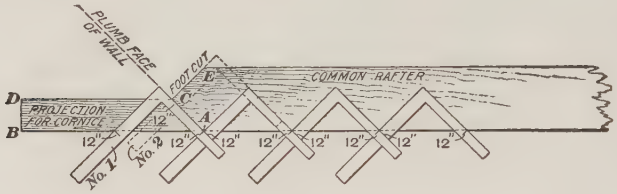

FIG. 20

ing rafters for the front gable may be cut by using the foot-cut just found as a templet, or pattern.

33. The rear gable rafter can next be laid out, and as the pitch is equal throughout the room, the same figures on the square are to be used to obtain the foot- and plumb-cuts. That is to say, the figures on the square that should be used are 12 inches on the tongue and 12 inches on the body. To obtain the length of the rafter, it will be necessary to step five times along the rafter timber, owing to the run being 5 feet. The operation of laying out the foot-cut is the same as that employed for the front gable rafter.

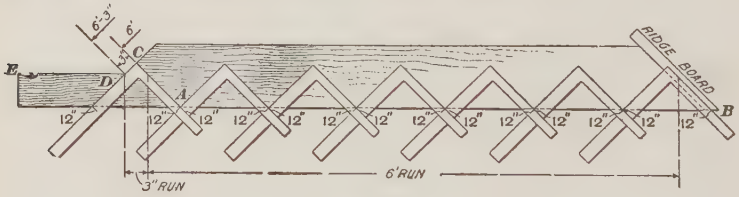

FIG. 21

34. The span of the left-side gable is 12 feet 6 inches; the run of the rafter, therefore, is 6 feet 3 inches. As the run of this rafter contains a fraction of a foot, the method of obtaining the length will be slightly different than that employed in laying out the rafters for the rear gable. Place

the square on the rafter timber as before, with 12 inches on the tongue and 12 inches on its body, and step along the timber six times, to determine the length for a 6-foot run.

To add the fractional part, 3 inches, proceed as shown in Fig. 21. The point *A* is the length found by stepping six times from the plumb-cut at *B*. Lay on the square at *A* as for another step, and from the heel *C* measure 3 inches along the body, as shown at *D*. Gauge the line *D E* the thickness of the projecting portion of the rafter beyond the plate, and draw the foot-cut along the body line through *D*, as shown.

35. The plan, Fig. 19 (*a*), shows that the four hips are of equal length, except that hip *G* is cut at a point where it intersects the ridge of the left-side gable. It is considered better construction if the hip is not made continuous from the ridge to the plate, as shown by the dotted line. If the hip were continued, it would be necessary to cut all the jack-rafters on the rear slope that run from the ridge to the rear plate. By cutting the hip off at the ridge, however, it affords a clean space from the plate to the dormer ridge, as shown in the rear elevation (*c*).

To lay out the long hip *H*, Fig. 19 (*a*), proceed by applying the square to the hip timber, with *17* on the tongue and *12* on the body; the tongue will give the foot-cut and the body will give the plumb-cut. To obtain the length of the rafter, it will be necessary to know the run of the rafter that spans from the plate to the ridge. The run of the rafter in this case is 11 feet. Place the square on the hip timber with *17* on the tongue and *12* on the body, and step eleven times; this will give the length of the rafter from the plate to the ridge.

It will be necessary to lay out the foot-cut, as in the case of the common rafter, but in order to do so the height that the hip is to be above the plate must be known, so that it can be made to coincide with the height above the plate of the common rafter. Referring to Fig. 22, which represents a corner of a building containing the lines of the plates and the seat of the hip, it will be seen that the seat of the hip

relative to the plate extends from C to A, and that the upper end of the hip, provided it is not backed, will coincide with the line $D\,E$, which is a square line to $A\,C$ drawn through A.

Referring now to Fig. 23, assume that the illustration represents the lower end of the hip rafter and that the point D is plumb with the plate. From point D, place square *No. 1* in the position shown as if about to measure the rafter by stepping, using *17* on the body and *12* on the tongue. Make $A\,D$ one-half the thickness of the hip rafter, which is equal to $A\,D$, Fig. 22, and make $D\,F$ equal to the thickness of the common rafter above the plate. As will be noticed, $D\,F$ also represents the thickness of the hip at the point where it intersects the plate, as shown at $G\,H$, Fig. 22, but as the hip is to extend to point A, Fig. 22, its thickness at this point is shown in Fig. 23 to be $A\,E$.

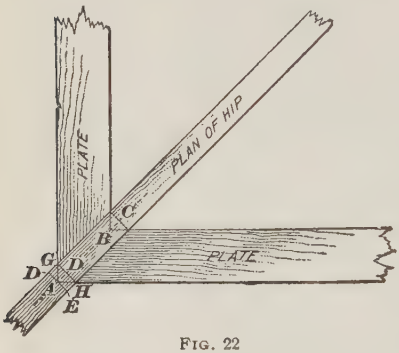

FIG. 22

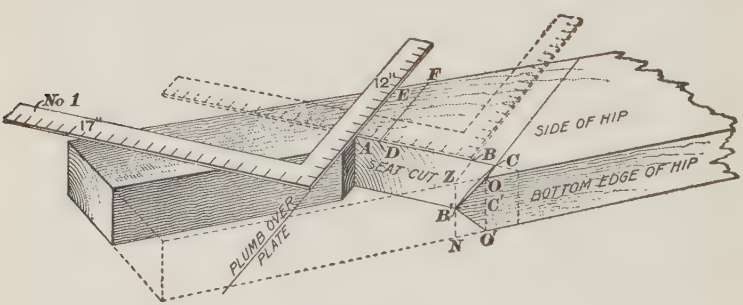

FIG. 23

36. In Fig. 23, at the bottom edge of the hip, is also shown the method of treating the bottom edge if a close fit against the plates is desired. It will be noticed that $A\,D\,B\,C$ on the seat cut, Fig. 23, is equal to $A\,D\,B\,C$, Fig. 22. From B, Fig. 23, draw $B\,Z$, and from C draw $C\,O$; also draw the

lines $OC'O'$ and $ZB'N$ square across the bottom of the timber. Connect B' and O, and B' and O'; then, cutting along these last two lines will frame the hip to fit against the plates at the internal angle B, shown in plan in Fig. 22. This hip is now complete, and may be used as a templet to lay out hips D and C, Fig. 19 (a).

37. To lay out hip G, which is shown in Fig. 19 (a), take 17 inches on the tongue and 12 inches on the body of the square, as was done in laying out the other hips. Step along the timber four times, and add $15\frac{5}{8}$ inches for the fractional part of a foot that the run contains. The run of the hip G can be found by taking the run of the main roof, which is 11 feet, and the run of the gable rafter, which is 6 feet 3 inches, and then deducting the 6 feet 3 inches from 11 feet, which gives 4 feet 9 inches.

To lay out a common rafter for this run, take *12* on the tongue and *12* on the body of the square and step four times along the rafter timber, completing the operation by adding 9 inches by the method illustrated in Fig. 21.

To lay out the hip, follow the method illustrated in Fig. 21. Having found the length of the hip rafter, the plumb-cut is found by marking along the side of the square that gives the rise. As this hip butts against the side of the ridge of the left-side gable, as shown at A, Fig. 19 (a), the foot-cut also will be found by marking along the rise. It will be noticed that both cuts are plumb, the top cut butting plumb against the side of the main ridge, as shown at H, Fig. 19 (a), and the bottom cut butting plumb against the side of the left-side gable ridge.

The cheek bevel of the hip to fit against the main ridge, shown at H, is obtained by taking the length of the rafter on the tongue and the run of the rafter on the body of the square, and marking along the tongue for the cut. The cheek cut for the abutment at A, if framed to fit against the ridge of the left gable, will be the same as that for the main ridge at H; but, if the abutment is framed to fit against the valley C, it will be a square cut from the side of hip.

38. To lay out valley *C*, which is shown in Fig. 19 (*a*), spanning from the plate to the hip *G*, take *17* on the body and *12* on the tongue and mark along the body for the foot-cut and along the tongue for the plumb-cut. To obtain the length of the rafter, step along the valley timber six times and then add for the 3 inches of run by the method shown in Fig. 21. The number of steppings for this valley is regulated by the run of the left-side gable rafter, which is 6 feet 3 inches. The cheek cut will be square across the back, so as to butt against the side of hip *G*.

39. To lay out the valley of the rear gable, Fig. 19 (*a*), marked valley *D*, use *17* on the body and *12* on the tongue for the foot- and plumb-cuts. As the run of the rear gable is 5 feet, it will be necessary to step five times along the valley timber to obtain the length. To frame the rafter so that the cheek cut will fit against the ridge of the rear gable, take the length of the gable rafter on the body and the run on the tongue and mark along the body for the cut.

40. To lay out valley *A* of the front gable, Fig. 19 (*a*), use *17* on the body and *12* on the tongue for the foot- and plumb-cuts. It will be noticed that valley *A* extends beyond the ridge of the front gable to the point marked *X*, and that it butts against the long hip *D*; therefore, this valley rafter will be the distance *MX* longer than its opposite valley *B*.

From *X*, drop a perpendicular line to the plates on the front gable at *Y*. Measure the distance from *Y* to the ridge at *N*, and add this distance to the 8 feet, which will give the total length of run of the valley rafter *A*. Assume that the run of the valley rafter is 10 feet; then, from this data, valley *A* may be laid out. Take *17* on the body of the square and *12* on the tongue of the square and step along the valley timber ten times, marking along the body for the foot-cut and along the tongue for the plumb-cut. The cheek cut to fit against the long hip at *X* will be a square cut across the back of the valley.

41. Valley *B* is shown to span from the plate to *M*, a point where the ridge of the front gable intersects valleys *A*

and *B*. To lay out valley *B*, take *17* on the body and *12* on the tongue and step along the valley timber eight times for the length. The cheek cut at *M* to fit against valley *A* will be a square cut.

42. To obtain the cuts for the jack-rafters, use the same figures on the square as for the common rafters; namely, *12* on the tongue and *12* on the body. The relative difference in length may be determined by the operation shown in Fig. 24, where square *No. 1* is shown placed on the jack-rafter timber with *12* on the body and *12* on the tongue. If 18 inches is determined on for the spacing between centers of jack-rafters, slide the square along the line of tongue 6 inches. The square will then be in the position shown by square *No. 2*; the heel will be at *A*, and both the body and

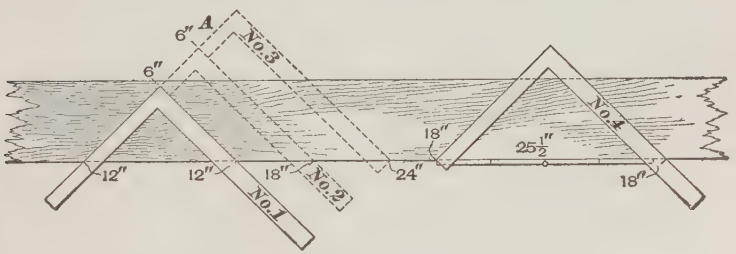

FIG. 24

the tongue will have the figures *18* where they intersect the side of timber.

By measuring with a 2-foot rule across the square from *18* on the body to *18* on the tongue, as shown at square *No. 4*, the distance will be found to be $25\frac{1}{2}$ inches, which is the length of the shortest jack-rafter. Twice this length will be the length of the second jack-rafter, three times will be the length of the third, and so on.

The bridge measurement from *18* to *18* on the square may be taken more accurately by laying the square on a board, and then, by means of a knife, marking at right angles to the edges of the square and along the edges, as shown in Fig. 25 (*a*). At (*b*) is shown the board with the square

removed. By measuring in this way, the marks on the board and the edges of the square are more sharply defined.

If the jack-rafters are to be placed 2 feet from center to center, the square will have to be put in the position shown by square *No. 3*, Fig. 24. The bridge measure will then be 34 inches, which will represent the length of the shortest jack-rafter. The rule is to slide the square so that the body will measure the distance that the jack-rafters are placed apart.

To find the cheek cut for the jack-rafters, so that they will fit against the sides of hips or valleys, take the length of the common rafter on the body and the run of rafter on the tongue and mark along the body of the square for the cut.

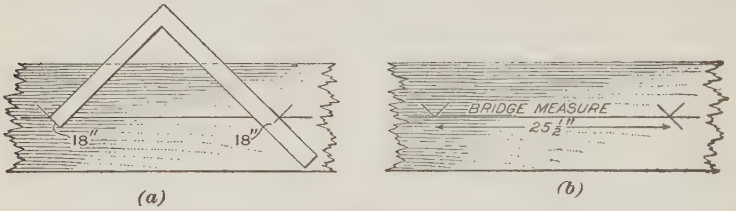

FIG. 25

Instead of the foregoing method, the cheek cut for a jack-rafter can be obtained by taking the length of the common rafter per foot of run on the body and 12 inches on the tongue and cutting along the body.

FRAMING AN UNEQUAL-PITCH ROOF

43. In the roofs thus far described, all the pitches of the several surfaces composing the same roof have been similar. Such roofs are called **equal-pitch roofs.** In **unequal-pitch roofs,** or those in which the several surfaces have two or more pitches, however, the square must be manipulated in a different manner when laying out the several rafters, which is due to the fact that all the runs and all the rises are not proportional. The elevation of all the ridges in the several parts of a roof may be the same, but the width of the several wings and bays may be different; consequently,

the rafters would have different runs. Again, all the runs may be alike, but the rises different; or, all the runs and all the rises may be different. Any of these conditions will form an unequal-pitch roof.

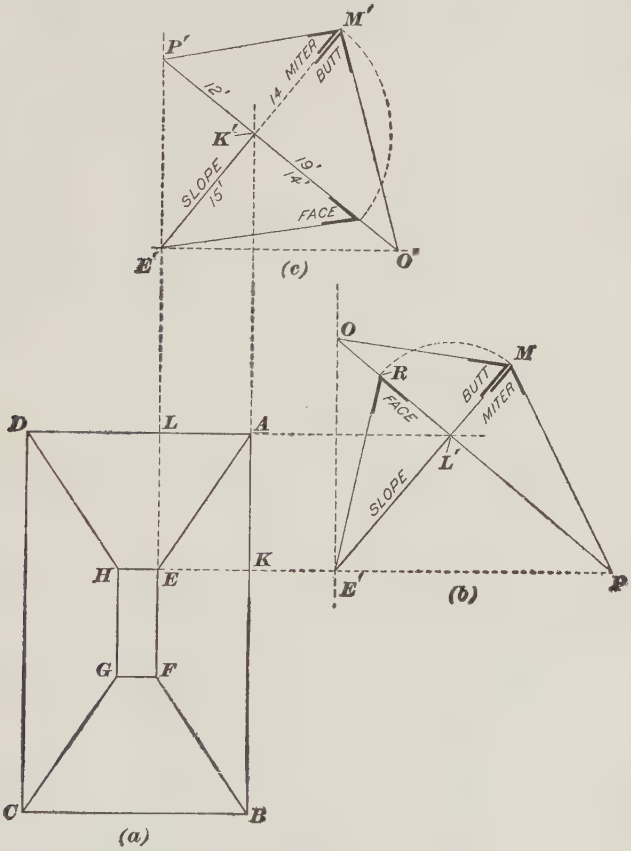

FIG. 26

44. Analyses of Hoppers.—Before describing unequal-pitch roofs, it may be well to analyze hoppers of unequal pitch, and then turn the hopper over, or upside down, and compare it with a roof. It will be found that the figures on the square to obtain the cuts for hoppers are identical with those used to obtain roof cuts of equal angles

Fig. 26 (*a*) shows the plan of a hopper of unequal pitch, *A*, *B*, *C*, and *D* being the top edges of the hopper, and *E*, *F*, *G*, and *H*, the bottom edges, or discharge side, of the hopper. The lines *A E*, *B F*, *C G*, and *D H* are the plan lines of the intersection of the sides and ends of the hopper, while *E K* is the plan width of one side and *E L* the plan width of one end.

45. In Fig. 26 (*b*) is shown the method of obtaining the cuts for the end pieces. Project the points *L E* at right angles to *A B*, in (*a*), and, from some point, as *E'*, draw a line *E' L'* at the desired pitch; this line will then represent the true length of *E L*. From *L'* and at right angles to *E' L'*, draw the line *O P*; produce the line *E' L'* to *M*, making *L' M* equal to *E K*, or the run of the side of the hopper. From *M* draw *M P* and *M O*; then, the angle *L' M P* will be the miter bevel, or the bevel across the edge of the board, and *L' M O* will be the butt bevel.

For the face bevel, or cut across the width of the board, make *L' R* equal to *L' M*, and connect *E' R*; then, the angle *E' R L'* will be the correct bevel to use.

46. In (*c*) is shown the method of getting the angles for the side pieces of the hopper. It will be noticed that the construction is the same as for the end. *E' K'* is the true length and slope of the side *E K*, and *K' M'* is equal to *L E*, or the run of the end. The miter butt and face cut are shown.

To find the figures on the square that will give the cuts, scale the distances *E' K'*, *K' P'*, *K' M'*, and *K' O'*. Assume that these distances scale 15, 12, 14, and 19, respectively, calling them either inches or feet. Then, for the miter cut, take 12 inches on the body of the square and 14 inches on the tongue of the square, and cut along the tongue; for the butt cut, take 19 inches on the body and 14 inches on the tongue, and cut along the tongue; for the face cut, take 15 inches on the body and 14 inches on the tongue, and cut along the tongue. The cuts of the ends may be obtained in the same way.

47. Comparison of Hoppers and Roofs.—The foregoing method, as applied to a hip-and-deck roof, is shown in Fig. 27, in which A, B, C, and D, in (a), represent the plates, and E, F, G, and H, the ridges. AE, BF, CG, and DH are the hips; EK, the run of the common rafter

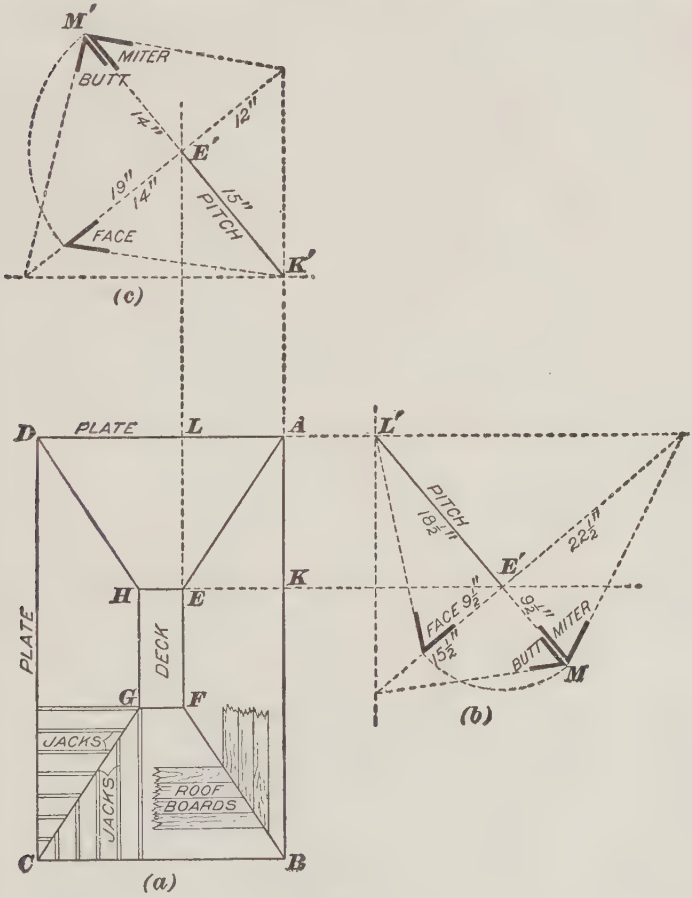

FIG. 27

on the narrow side; and EL, the run of the common rafter on the end. In (b), $L'E'$ is the pitch of the common rafter on the ends, and in (c), $K'E'$ is the pitch of the common rafter on the narrow side.

It will be observed that the construction in Fig. 27 (*b*) and (*c*) is the same as that in Fig. 26 (*b*) and (*c*), with the exception that the pitch in the roof timber is in a different direction than the slope of the sides of the hopper. The several pitches of the roof and the various slopes of the hopper are the same, and the figures to use on the square are found to be identical.

The angles shown will give the bevels at which to cut the roof boards to fit on the hips, also the bevels to cut the planchers and the bevels to miter the purlins. All of these bevels are similar.

48. The cut for the roof board on its face, or the cut to make it fit with the center line of the hip, is called the *face bevel*. The figures to use on the square for the boards on the end $BCGF$ are those shown in Fig. 27 (*b*); namely, $18\frac{1}{2}$ inches on the body and $9\frac{1}{2}$ inches on the tongue, the cut to be along the tongue. For the jack-rafter, the body of the square will give the side cut. To miter the roof boards, take $22\frac{1}{2}$ inches on the body of the square and $9\frac{1}{2}$ inches on the tongue of the square, and cut along the tongue. The foregoing figures applied in the same way will also give the cut for purlins and planchers. The butt bevel is seldom used in roof framing, but in some cases it can be used instead of the miter bevel. The figures to use for the butt cut are $15\frac{1}{2}$ inches on the body of the square and $9\frac{1}{2}$ inches on the tongue of the square, cutting along the tongue.

49. The face bevel is the one most frequently used in roof framing; therefore, a method will be given for applying this bevel in fitting roof boards to hips on roofs of unequal pitch. By referring to Fig. 27, it will be noticed that EK, in (*a*), is equal to $E'M$, in (*b*), and that $L'E'$ is equal to the length of rafter in the end of the roof. In other words, EK is the run of the right side of the roof, and $L'E'$ is the length of rafter in the left side of the roof. Again, LE, in (*a*), is equal to $E'M'$, in (*c*), and $E'K'$ is equal to the length of the rafters in the narrow roof; or, LE is equal to the run of the rafters in the left side of the roof, and $E'K'$ is equal to

the length of rafter in the right side of the roof. For the face cut of roof boards to fit over the hip in the left side of the roof, take the length of the common rafter ($L'E' = 18\frac{1}{2}$ inches) in the left side of the roof on the body of the square and the run of the common rafter ($EK = 9\frac{1}{2}$ inches) in the right side of the roof on the tongue of the square and cut along the tongue. For the face cut on the right side of the roof, to fit over the hip, take the length of the right common rafter ($E'K' = 15$ inches) on the body of the square and the run of the left common rafter ($LE = 14$ inches) on the tongue of the square, and cut along the tongue. For the face cut of jack-rafters, use the same figures on the square, but cut along the body.

50. Valley Roof of Unequal Pitch. In Fig. 28 is shown the plan of a valley roof of unequal pitch. The run of one side of the roof is 16 feet and that of the other is 7 feet, while the rise of each side is 16 feet. The following method may be employed to find the figures on the square to be used to obtain the required cuts and lengths of the common rafter of the main roof. For the run and the rise, each equal to 16 feet, reduce the 16 feet to inches, which will give 192 inches run and 192 inches rise. To reduce these figures to the limit of the square, divide each by the same figure. In this case, divide by 16; thus, $192 \div 16 = 12$, which is used for both the run and the rise. With 12 inches on the tongue of the square and 12 inches on the body of the square, the foot-cut and the ridge cut are obtained; and by stepping along the rafter timber sixteen times, the length of the rafter will be determined

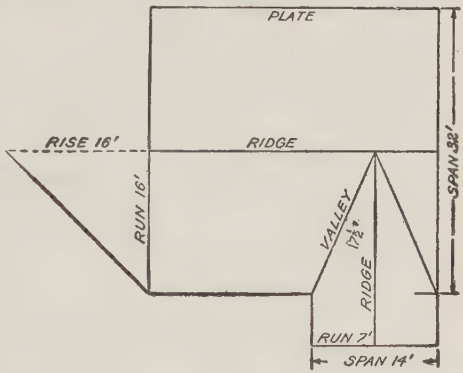

FIG. 28

To obtain the figures on the square for the rafters having a 7-foot run and a 16-foot rise, reduce the 7 feet to inches; thus, $7 \times 12 = 84$ inches. The rise has already been found to be 192 inches, and to reduce these figures to the limit of the square divide by 12, which will give 7 inches for the run and 16 inches for the rise. Take 7 inches on the tongue of the square, and 16 inches on the body of the square; the tongue will give the foot-cut and the body will give the plumb-cut. To obtain the length of the rafter, step along the rafter timber twelve times with the square, because 12 was the divisor.

By similar operations, the cuts and lengths of the valley rafters can be obtained. The rise of the valley rafters is known to be 16 feet, and the run can be determined either by scaling from the plate to the ridge along the plan line or by measuring the diagonal from 16 inches on the body of the square to 7 inches on the tongue of the square. The run of the valleys is practically $17\frac{1}{2}$ feet; then, by taking $17\frac{1}{2}$ inches on the tongue and 16 inches on the body, the tongue will give the foot-cut and the body will give the plumb-cut. For the length, step along the valley timber twelve times with the square.

51. Hip and Valley Rafters for Roofs of Unequal Pitch.—Fig. 29 shows a method of finding the figures on a square to lay out hips and valleys for roofs of unequal pitch. Let AB represent the run of a common rafter, BC the rise, and CA the pitch. The body of square *No. 1* indicates a 12-inch run, and the tongue a 7-inch rise, which means that the rafter rises 7 inches per foot of run. Let BD represent the run of the rafter on the other side, BE the rise, and DE, the pitch. It will be noticed that the pitch of the rafter AC will not be the same as that of rafter DE, the latter being much steeper than the rafter AC. This is due to the fact that both rafters have the same total rise, but have different runs.

The seat angle of the hip, which is determined by the two pitches, will stand at an angle of 30° with the plates, as

shown by the line *B F*. The figures to use on the square for the foot- and plumb-cuts of the hip while in this position are shown on square *No. 2* to be $13\frac{7}{8}$ inches on the body, for the run, and 7 inches on the tongue, for the rise. The length

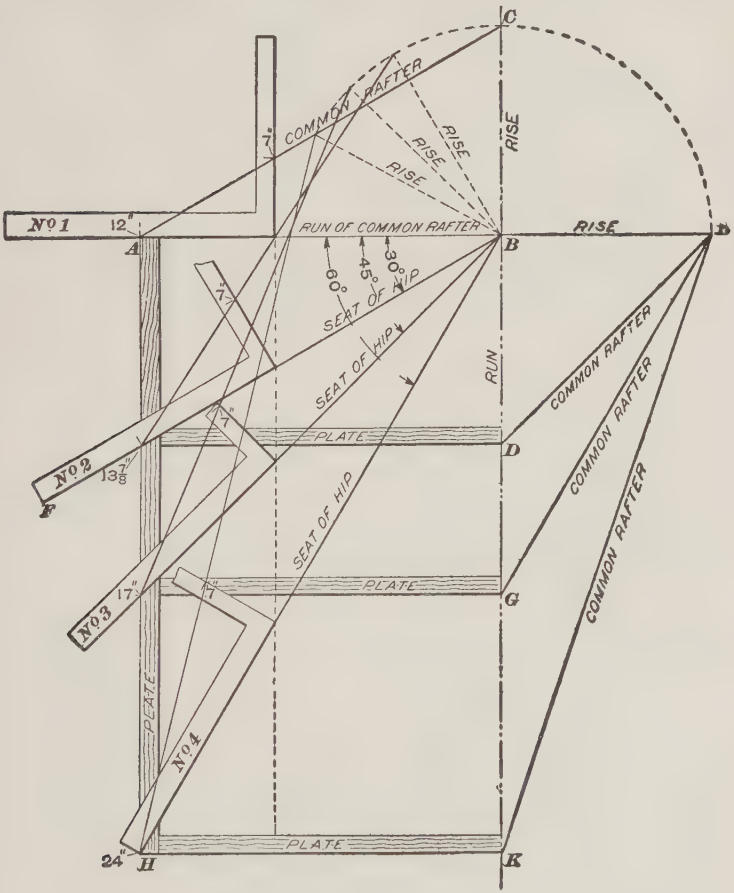

FIG. 29

can be determined by stepping along the hip timber the same number of times as for the common rafter.

52. In Fig. 29 is also shown the seat of a hip standing at an angle of 45° with the plates, and a common rafter *G E*

that has the same pitch as the common rafter *A C*. As the two common rafters have equal pitches, they make an equal-pitch roof; consequently, the figures on the square to use for the foot- and the plumb-cuts of the hip rafters are *17* and *7*.

The line *B H* shows the seat of a hip at an angle of 60° with the plate; on the right is the common rafter *E K*, and

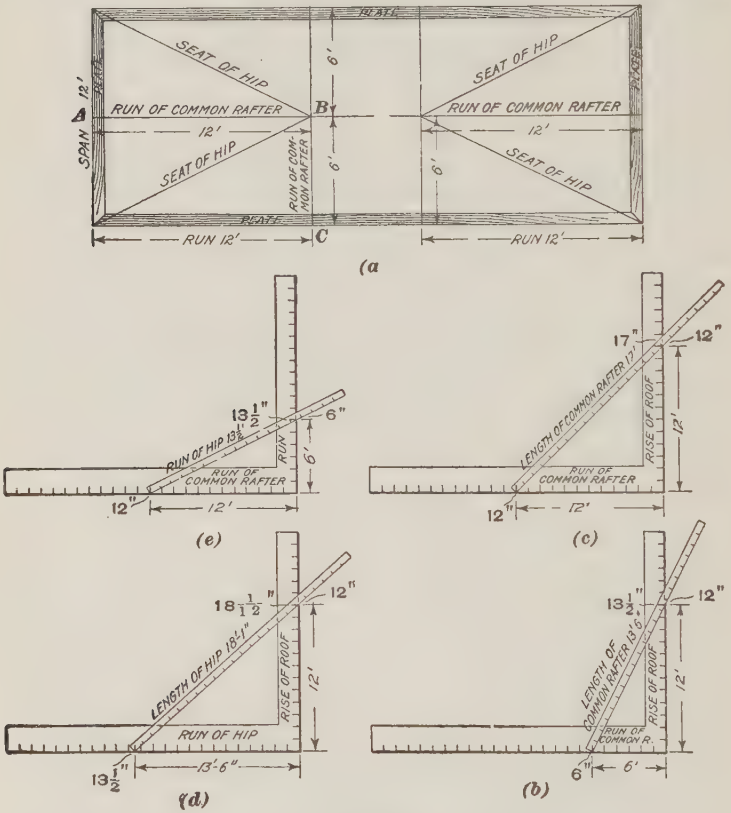

FIG. 30

on the left, the common rafter *A C* corresponding to this hip. On square *No. 4* are the figures to use for the foot- and the plumb-cuts of the hip rafter. The figures on the body remain constant for hips placed at these angles, but the figures on the tongue change as the rise of the common rafter changes.

53. Hip Roof With Unequal Pitches.—The hip roof shown in Fig. 30 (*a*) rises 12 feet, while the sides have a much steeper pitch than the ends. The variation in the seat angle of hips and valleys causes many difficulties in framing roofs of this kind. In roofs of equal pitch, the seat angle of the hip or valley is always known, while in unequal-pitch roofs there is no standard seat angle, and consequently, the figures on the square that will have to be used to obtain the cuts and lengths of hips and valleys must be found in each special case, according to conditions arising from differences involved in the pitches. Also, in roofs of unequal pitch, a great many complex problems affecting the layout of jack-rafters, roof boards, planchers, and every other timber that enters into the construction, are likely to arise.

54. In the plan shown in Fig. 30 (*a*), the rafters on the side have a run of 6 feet, while those on the end have a run of 12 feet. Both rafters, however, have the same rise. To lay out the rafter *C B*, use *12* on the tongue of the square for the run and *24* on the body of the square for the rise, because the rafter rises 12 feet in 6 feet, which is the same as a rise of 24 inches in 12 inches. For the length of the rafter, step with the square six times, using the figures *12* and *24*; or, to save time in stepping, take the bridge measure of *12* and *24* and multiply it by 6. Another method is to take the bridge measure of *6* and *12* and call the inches feet, as shown in Fig. 30 (*b*).

To lay out the end rafter *A B*, use *12* on the body of the square and *12* on the tongue of the square for the cuts. For the length of the rafter, step twelve times along the rafter timber, or, as before described, take the bridge measure as shown in (*c*). The figures made use of on the square for both of these rafters will give, for each slope, a rafter that will have a total rise of 12 feet. For the rafter *C B*, 12 inches on the tongue for the run, and 24 inches on the body for the rise should be used, while the length is found by stepping off six times; now, multiplying 24 inches by 6 will give 144 inches, or 12 feet, for the rise. In laying out rafter *A B*.

12 inches on the body of the square and 12 inches on the tongue of the square should be used, and the length can be found by stepping twelve times; consequently, the rise is $12 \times 12 = 144$ inches, or 12 feet.

55. In laying out a hip, the first thing to consider is its length, which may easily be found by means of a 2-foot rule and a steel square. Place the rule across the square, from *12* on the body to *6* on the tongue, as shown in Fig. 30 (*e*); the rule will indicate a distance of 13 feet 6 inches, which is the correct length of the run of the hip. Having determined the run, take the bridge measure of this run and the total rise on the square, or $13\frac{1}{2}$ inches on the body and 12 inches on the tongue, as shown in (*d*). The length, therefore, will be 18 feet 1 inch.

56. By referring to Fig. 31, the operation of framing rafters for unequal-pitch roofs may be further explained.

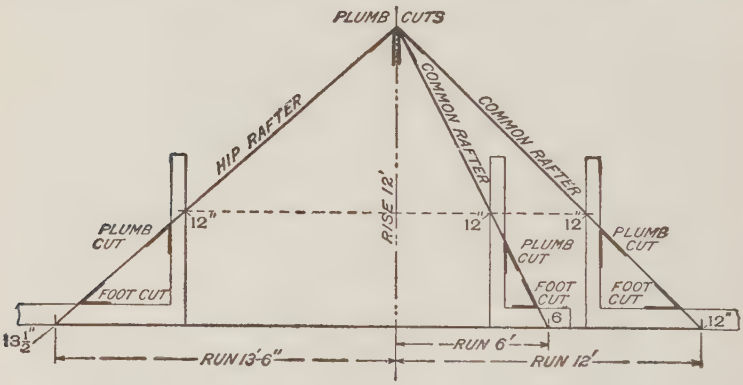

Fig. 31

This figure illustrates the principles underlying the handling of the square in this connection. On the right side is shown the pitch of the rafter over the ends of the building. These rafters have a rise of 12 inches per foot of run. The square as applied shows the figures *12* on the body and *12* on the tongue, which are the ones to be used for the foot- and plumb-cuts. On the same side is also shown the rafter for

the narrow side of the roof, and the figures *6* and *12* indicate the position of the square when marking the rafter for the foot- and plumb-cuts, *6* and *12* being in the same proportion as 12 and 24. On the left side of the illustration is shown the hip rafter, and the figures on the square used for the foot- and plumb-cuts.

57. Another method of ascertaining the run of a hip, relative to a foot-run of a common rafter, is shown in Fig. 32, in which the plan lines of two of the hips are represented by *A C* and *B C*, and the plan line of a common rafter by *D C*. The method consists in measuring 12 inches from *D* to *E* on the rafter line *D C*, as shown, and drawing the line *E F* at right angles to *D C*, cutting the plan line of hip *B C* at *F*. The portion *B F* of the hip line indicates the foot-run of the hip relative to a foot-run of the common rafter.

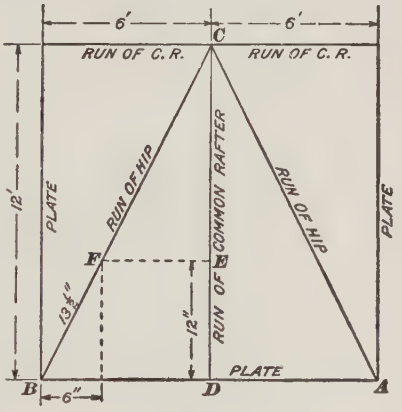

FIG. 32

58. The bevels for the jack-rafters and roof boards are shown in Fig. 33, which is a plan of the roof shown in Fig. 30 (*a*). In Fig. 33, *C D E F* represents the plates. To show how the figures to cut the jack-rafters and roof boards are obtained, it will be necessary to unfold the roof, that is, to show the roof surfaces laid in a horizontal position. In order to do this, imagine that the roof is hinged at the plates, so that the four surfaces can be opened like the lid of a box, the joints of the lid being the four hip rafters and the ridge of the roof. Now, if this lid is laid in a horizontal position, the plan lines of the hips will be the true lengths; but, as the lid is inclined from the horizontal, it is evident that the true lengths of the joints, with the exception of the ridge, will be longer than the plan lines show. The lengths of the ridge line will be

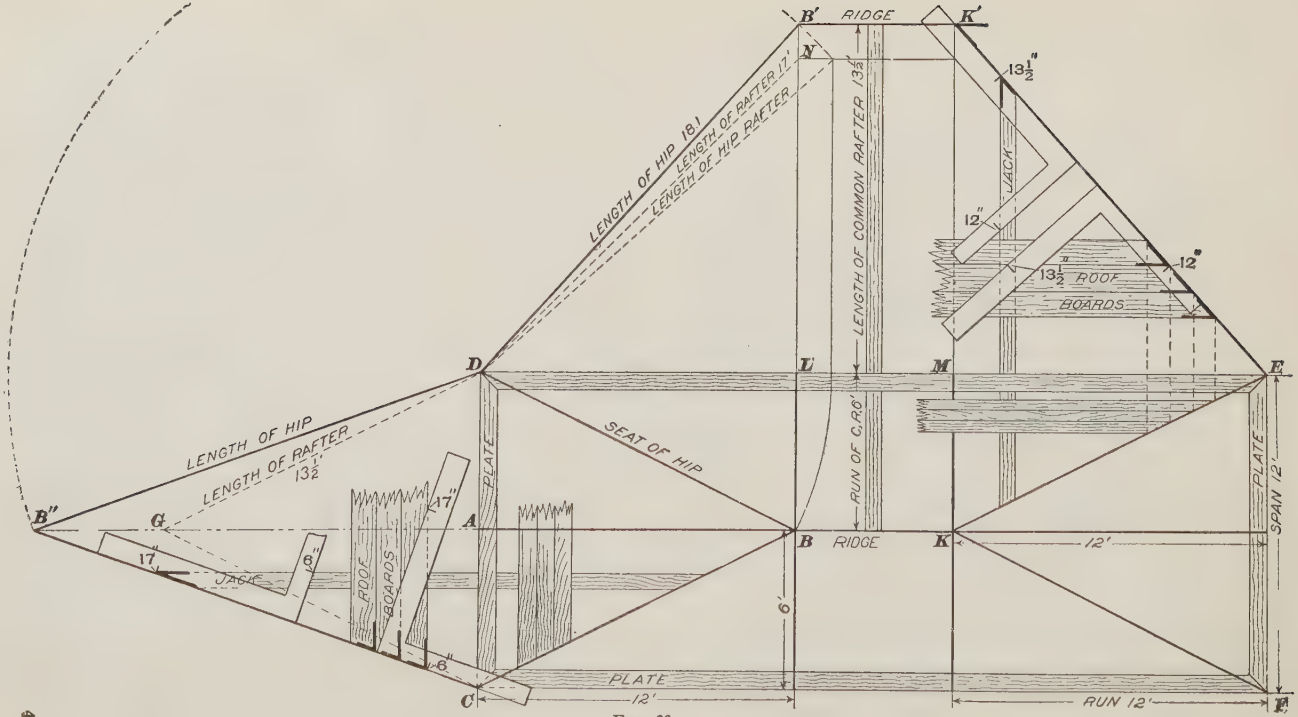
B'
RIDGE
K'
N
LENGTH OF HIP 18'
LENGTH OF RAFTER 17'
LENGTH OF HIP RAFTER
LENGTH OF COMMON RAFTER 13½'
13½"
JACK
12"
12"
13½" ROOF BOARDS
D
L
M
E
LENGTH OF HIP
LENGTH OF RAFTER 13½'
SEAT OF HIP
PLATE
RUN OF C,R 6'
PLATE
SPAN 12'
B"
G
A
B
RIDGE
K
12'
17"
17'
JACK
9"
ROOF BOARDS
6"
6'
C
PLATE
12'
RUN 12'
F

FIG. 33

the same, because it is a horizontal line and is also parallel with the hinged line, or line of plates.

59. First, consider the long, narrow section of roof. Let DE be the line along which the roof is hinged, and DB, BK, and KE the joints; then, by opening the lid and bringing it into a horizontal position, the points B and K will rest at B' and K', and in order to lay out this surface, all that is necessary is to find the points B' and K'. Now, BL is the plan of a line on the lid; in this case, it is the plan of the common rafter. The true length of this line is shown at DG. By making LB' and MK' each equal to GD, and connecting $B'D$ and $K'E$, the true size and shape of $DBKE$ will be shown at $DB'K'E$. Any lines or angles laid on this shape will be the true lengths and angles; consequently, the lines DB' and $K'E$ equal the true lengths of the hips.

The bevels shown for the roof boards and the jack-rafters are the true bevels, and the figures to use on the square are taken from the triangle EMK'. ME is the run of the common rafter on the end, and MK' is the length of the common rafter on the side. Then, by taking ME on the tongue of the square and MK' on the body of the square, and cutting along the body, the cheek cut of the jack-rafters will be given. As the roof boards are placed at right angles to the jack-rafters, the figures on the square used to obtain the cuts of the jack-rafters will give the face cut of roof boards, but instead of the body giving the cut, it will be necessary to cut along the tongue. The angle, or bevel, shown at K' is the one to use for the side cut of a hip rafter when it is backed. This bevel is the same as for the roof boards, and the one to use for planchers.

60. The end lid is developed in exactly the same manner as the side. Lay off the line AB'' equal to the length of the common rafter DN; connect $B''D$ and $B''C$; and these last two lines will be equal in length to the hips. When the plan DBC is opened and turned to a horizontal position, the point B will revolve to B''. The figures on the square

to use for the side cuts of jack-rafters and roof boards will be obtained from the distance $A\,C$, which is equal to the run of the common rafters on the side of the roof, and $A\,B''$, which is equal to the length of the common rafters on the end of the roof. From the foregoing description, rules may be formulated for finding the figures on the square to use when laying out jack-rafters and roof boards for unequal-pitch roofs, provided the ridges are of the same height.

Rule I.—*To find the cheek cuts of jack-rafters in the side of the roof, take the run of the common rafter in the end of the roof on the tongue of the square and the length of the common rafter in the side of the roof on the body of the square, and cut along the body.*

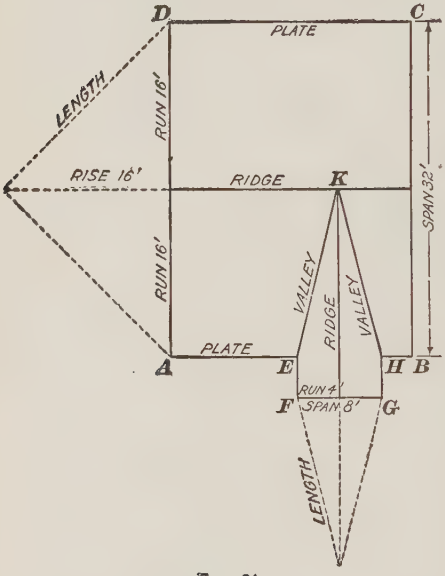

FIG. 34

Rule II.—*To find the cheek cuts of jack-rafters in the end of the roof, take the run of the common rafter in the side of the roof on the tongue of the square and the length of the common rafter in the end of the roof on the body of the square, and cut along the body.*

Rule III.—*To find the cut for roof boards, use the same figures on the square as for laying out the cheek cut for jack-rafters, but cut along the tongue instead of the body.*

61. Valleys on Roofs of Unequal Pitch.—Although the length and cut of valley rafters are very similar to those of hip rafters, it may be well to show an example of a valley roof of unequal pitch. Fig. 34 illustrates the plan of such a roof. In this illustration, $A\,B\,C\,D$ represents the plates of

the wide roof, and *E F*, *F G*, and *G H* the plates of the narrow roof. The run of the rafter on *A D* is 16 feet, and on *F G*, 4 feet. Each roof has the same rise and their ridges intersect at *K*. The seats of valleys are shown to reach from *E* to *K* and from *H* to *K*. The methods of determining the lengths of the rafters have already been explained. The figures to be used in obtaining the foot- and the plumb-cut for the valley rafters are *16½* and *16*, while the length may be found by stepping twelve times along the valley timber. These figures are derived by reducing the run and the rise to inches and dividing by 12.

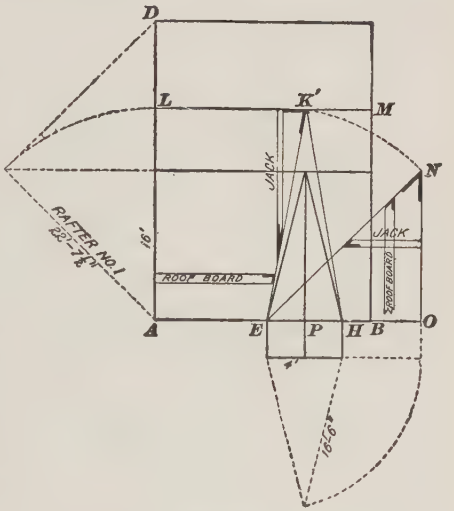

FIG. 35

62. Fig. 35 shows the same plan lines as those given in Fig. 34. By revolving rafter *No. 1* to *L* and drawing the line *L M* parallel with the ridge, the figure *A L M B* will show the true size and shape of one side of the main roof, in which *A L* and *M B* are the true lengths of the common rafters. The point *K'* is where the ridge of the small roof intersects the ridge of the main roof. Connect *K'* and *E*, and *K'* and *H*; then, these two lines will represent the true length of the valley rafters, and the bevel shown at *K'* will be the cheek cut for the valley rafter, provided it is backed. Revolve the valley *E K'* to *N*, connect *N* and *E*, and make *E O* equal to the length of the gable rafter in the small roof; also connect *N* and *O*. Then *N O* will equal the run of the common rafters in the main roof, and *E O*, the length of the common rafters in the small roof. The triangle *E O N* represents the true size

and shape of one side of the small roof, when it is laid in a horizontal position.

The bevel shown in N is the true bevel for the cheek cut of the valley rafter, to fit against the ridge of the small roof, provided the valley is backed. The true cheek and face cuts of jack-rafters and roof boards are shown, and the figures to use on the square are found in the same manner as shown in Fig. 33. For the side cuts of jack-rafters on the small roof, take the run of the common rafters on the large roof, which is equal to NO on the tongue of the square

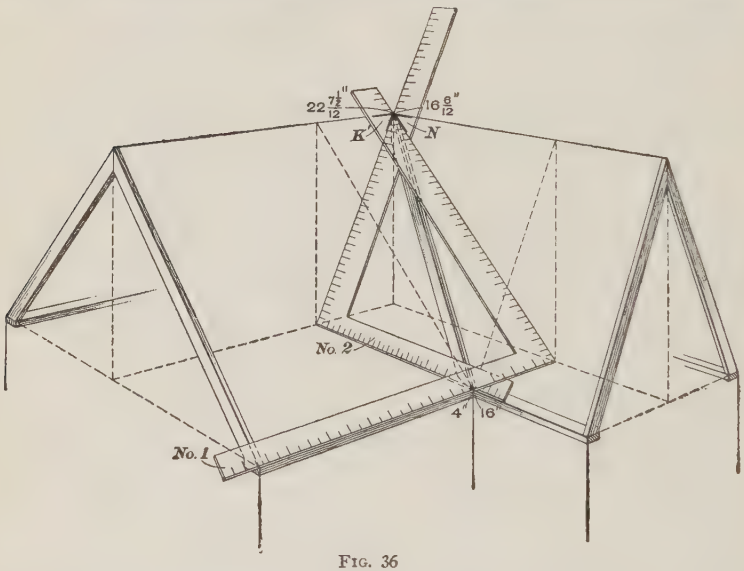

FIG. 36

and the length of the common rafter on the small roof, which is equal to EO, on the body of the square, and cut along the body. For the side cut of jack-rafters on the large roof, take the run of the common rafter in the small roof, which is equal to EP on the tongue, and the length of the common rafter in the large roof, which is equal to PK' on the body, and cut along the body. For roof boards, cut along the tongue of the square. For the bevel N to fit the valley on the small ridge the same figures are used as for

roof boards, and the bevel at K' is set at the angle used for cutting the roof boards.

63. Fig. 36 shows a perspective view of an unequal-pitch roof with two squares applied to the valley in such a position that they will probably illustrate more clearly why certain figures on the square are used. It will be noticed that square *No. 1* has the run of the small roof and the length of the rafter in the large roof, while square *No. 2* has the run of the large roof and length of the rafter in the small roof. It should be remembered, however, that these bevels for the side cut of valleys hold true only when the valley is backed.

64. Laying Out Unbacked Hip or Valley Rafters. In roof framing, valleys and hips are seldom backed, the practice being to use the timber in the rough, as received from the yard. When hips and valleys are not backed, the figures to use on the square to obtain the side cut are different than when backed. This difference is due to the fact that the top edges of the timber are not in the same plane with the roofs on either side. The backing of a hip or a valley brings both top edges in the same plane with the intersecting roofs. In order to find the figures for getting the side cut when timber is not backed, it is necessary to make a drawing, as no rule can be formulated that will hold true for the various combinations of intersecting roofs.

Owing to the fact that the seat of the hip or the valley in equal-pitch roofs stands at an angle of 45°, the expression for side cut remains constant for every pitch. This expression may be stated in the form of a rule, thus:

Rule.—*To find the side cut for hip or valley rafters on equal-pitch roofs, take the run of the hip or the valley on the body of the square and the length of the hip or the valley on the tongue of the square, and cut along the tongue.*

65. In Fig. 37 is shown a method of finding the figures to use on a square in making the side cut of hip or valley rafters when the timbers are not backed. The roof shown in

this figure is the same as that shown in Figs. 34 and 35, and the development of the roof surface and the point K is the same as in Fig. 35. The line EK', Fig. 37, is the true length of the valley rafter. To find the cheek bevel, or side cut, of

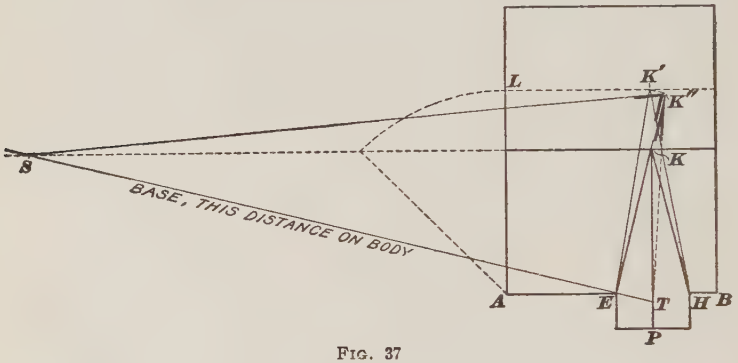

FIG. 37

a valley rafter to fit against the main ridge, produce the seat of valley EK to EK'', making the latter equal in length to EK'. Produce the line of the main ridge to S. From the point E, where the valley intersects the plates, draw ES

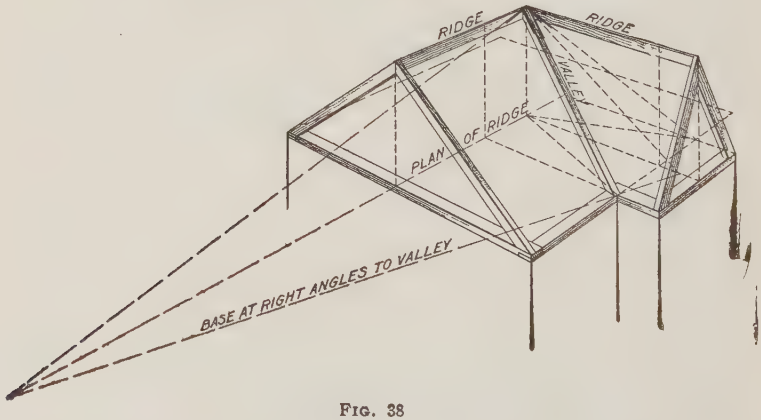

FIG. 38

at right angles to EK, and connect S and K''; then, $SK''E$ will be the correct angle to use. The figure to use on the square will be the distance ES on the body, and the distance EK'', which is equal to the length of the valley, on the

tongue, the tongue giving the cut. It will be observed that the line marked *base* will change as the seat of the valley changes. When the seat of the valley makes an angle of 45° with the plates, then the base will be equal to the seat of the valley, or will have the same length as the run.

To find the bevel of the valley, after the fit against the dormer ridge, draw the line $E\,T$ at right angles to $E\,K$ and connect T and K''; then, the angle $E\,K''\,T$ will be the correct bevel for the cut of the valley rafter. The figures to use on the square will be the distance $E\,T$ on the body and $E\,K''$, which is equal in length to the valley, on the tongue, cutting along the tongue.

A perspective view of the roof shown in Fig. 37, containing the construction lines, is illustrated in Fig. 38. As shown in this view, the back of the valley timber, as placed in position at the intersection of the two roofs, is square, while in Fig. 36 the valley is run in line with the plates, as they would do when backed.

66. Ridges of Different Heights.—When the ridges of a roof of unequal pitch are not the same height above the plates, the expressions on a square to obtain the cuts are somewhat changed. Fig. 39 shows a roof in which the dormer ridge does not extend so high above the plates as the main ridge. In the illustration, $A\,B\,C\,D$ represents the plates of the main roof; $E\,F\,G\,H$, the plates of the dormer; $E\,J$, the seat of the short valley; and $H\,K$, the seat of the long valley.

To find where the valleys intersect in the plan of the main roof, produce the line of the main ridge to M. Make $N\,M$ equal to the rise of the main roof, and $N\,O$ equal to the rise of the dormer roof. Connect A and M; then, $A\,M$ will represent the length and pitch of the main roof. From O, lay off a right angle to $M\,N$, and this line will intersect the pitch line at P; then, $O\,P$ will represent the plan distance from the ridge to where the valleys intersect, and $M\,P$, the true distance along the roof from the ridge where the valleys intersect. From P, draw the line $P\,J$ parallel with the ridge line,

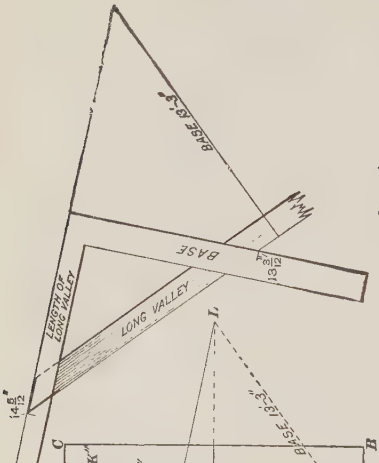

FIG. 40

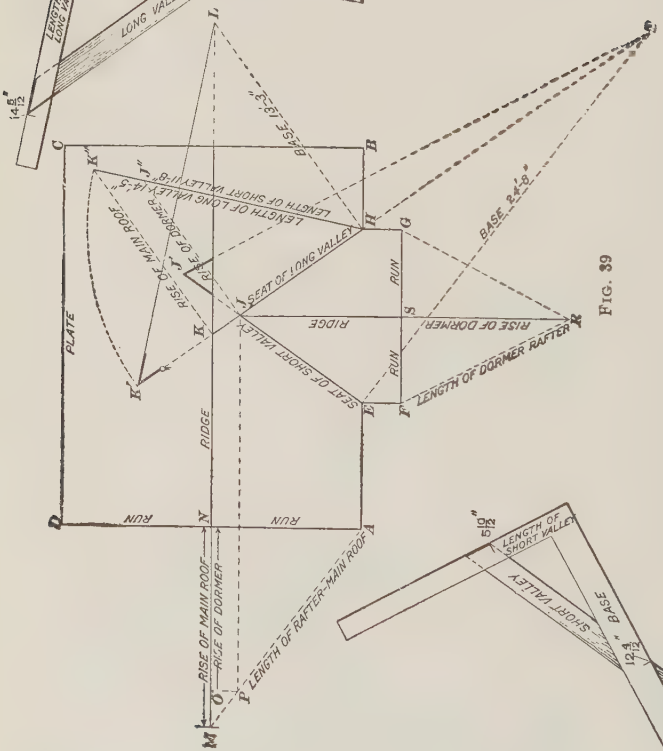

FIG. 39

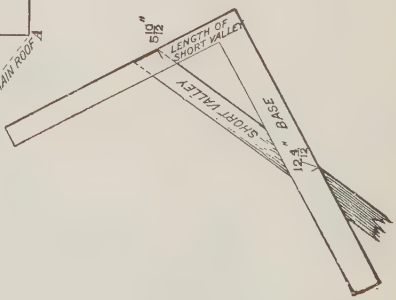

FIG 41

and where this line intersects the ridge line of the dormer will be the point of intersection of the valleys in the plan.

67. The seat of the long valley can be determined by drawing a line from H, Fig. 39, through J, to the ridge at K. The seat of the short valley will be the line EJ. The length of the dormer rafter will be found by laying off the line SR equal to the rise of the dormer ON and connecting F and R, and G and R; then, FRG will be an elevation of the dormer rafter, and FR the length of the common rafter in the gable.

To find the lengths of the long and short valleys, erect perpendiculars to HK at J and K, making KK'' equal to the rise of the main roof, and JJ'' equal to the rise of the dormer roof. Connect K'' and H—this line will also pass through J''—then HK'' will be the length of the long valley, and HJ'' the length of the short valley. For the foot- and plumb-cuts, take KH on the body of the square, and KK'' on the tongue of the square; the body will give the foot-cut and the tongue will give the plumb-cut for both valleys.

To find the bevel of the long valley to fit against the main ridge, erect a perpendicular to HK at H; this line will intersect the main ridge, or ridge produced, at L. Produce the seat of the valley to K', making HK' equal in length to the long valley. Connect LK'; then the angle $LK'H$ will be the desired bevel. The figures to use on the square will be found by taking the distances HL on the body and HK' on the tongue, and cutting along the tongue. Fig. 40 shows the application of the square.

68. To find the side cut to fit the short valley against the long valley, make EJ', Fig. 39, equal in length to the short valley, and produce the long valley to T. Erect at E a perpendicular to the seat of the short valley; this line will intersect the produced line of the long valley at T, and the angle $EJ'T$ will be the desired bevel. The figures to use on the square will be the base ET on the body and the length of the short valley EJ' on the tongue, cutting along the tongue. The method of finding the bevel to fit the short valley against the ridge has already been explained. The

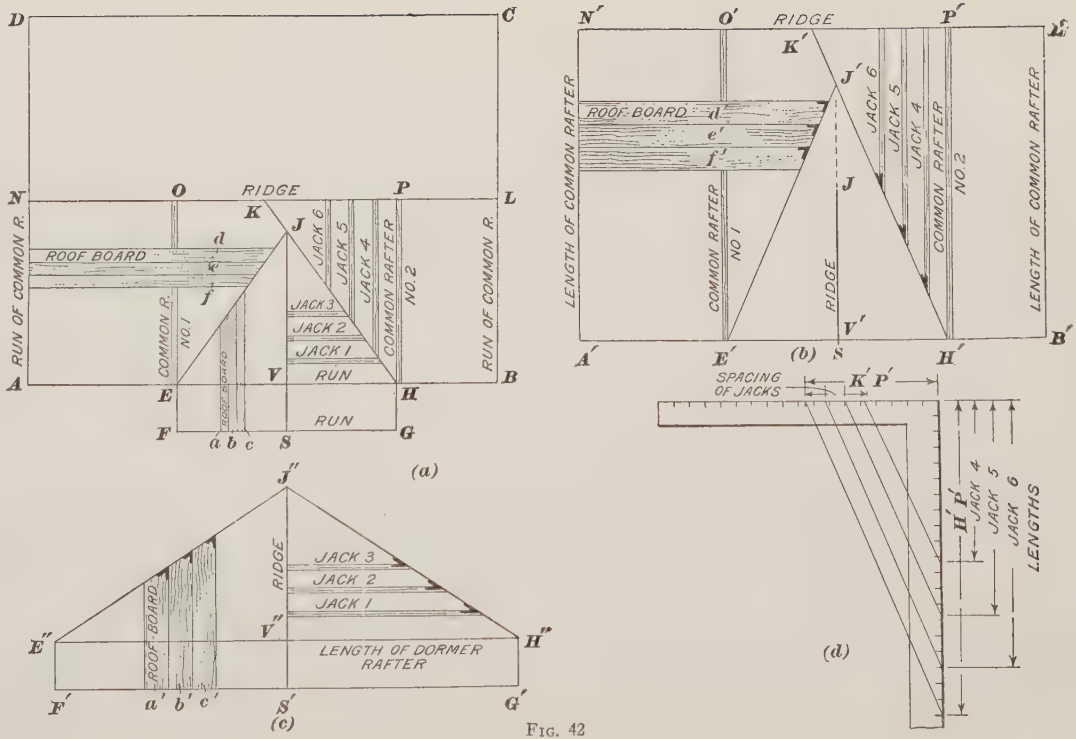
D
C
N
O
RIDGE
P
L
K
J
JACK 6
JACK 5
JACK 4
JACK 3
JACK 2
JACK 1
COMMON RAFTER NO. 2
ROOF BOARD
d
e
f
COMMON R. NO. 1
RUN OF COMMON R.
RUN OF COMMON R.
A
E
V
RUN
H
B
F
a b c
S
RUN
G
(a)
J''
RIDGE
JACK 3
JACK 2
JACK 1
ROOF BOARD
V''
E''
H''
LENGTH OF DORMER RAFTER
F'
a' b' c'
S'
G'
(c)
N'
O'
RIDGE
K'
P'
L'
J'
JACK 6
JACK 5
JACK 4
COMMON RAFTER NO. 2
ROOF BOARD
d'
e'
f'
J
LENGTH OF COMMON RAFTER
COMMON RAFTER NO. 1
RIDGE
V'
LENGTH OF COMMON RAFTER
A'
E'
(b)
S
H'
B'
SPACING OF JACKS
K'
P'
H'
P'
JACK 4
JACK 5
JACK 6
LENGTHS
(d)

FIG. 42

application of the square to the short valley is shown in Fig. 41.

As the length of the base is beyond the limits of the square, it is necessary to reduce the distances. In order to do this, divide both the length of the base, which is 24 feet 8 inches, and the length of the short valley, which is 11 feet 8 inches, by 2, thus giving $12\frac{4}{12}$ inches for the figures on the body, and $5\frac{10}{12}$ inches for those on the tongue. These figures will give the same angle as the figures 24 feet 8 inches and 11 feet 8 inches.

69. The expression for the side cuts of jack-rafters and for the face cuts of roof boards changes when the ridges are not of the same height; this is due to the run of the main roof not being the same as the length of the dormer ridge from the plate to the intersection of the roofs. Fig. 42 (*a*) represents the same plan as that shown in Fig. 39. On one side of the dormer, the jack-rafters are shown in place, and on the other side, the roof boards. It will be noticed that the dormer ridge VJ is shorter than the run of the common rafter in the main roof; consequently, the distance along the ridge KP is longer than the run of the dormer rafter. If the ridges were of the same height, the ridge JV would be equal to the common rafter PH, and the distance KP would be equal to the run VH of the dormer rafters. Owing to these changed conditions in the length of runs, under different conditions, it will be necessary to find an expression on the square that will cover every case.

70. Fig. 42 (*b*) shows a development of one side of the main roof; in other words, it shows one side laid down flat, or in a horizontal position. The lengths of the common rafters are taken from Fig. 39.

To make the development shown in Fig. 42 (*b*), draw $A'B'$ equal in length to AB, in (*a*); lay off $A'N'$ and $B'L'$ at right angles to $A'B'$ and equal in length to the common rafter in the main roof; and draw $N'L'$ equal in length to the ridge NL, in (*a*). On the line $A'B'$, in (*b*), lay off $A'E'$, $E'V'$, and $V'H'$ equal to AE, EV, and VH, in (*a*).

On the line $N'L'$, lay off $N'K'$ equal to NK, in (a); connect K' and H', and $K'H'$ will be the length of the long valley. From V' erect a perpendicular to $A'B'$, intersecting $K'H'$ at J'; connect J' and E', and $J'E'$ will be the length of the short valley. As will be noticed, all lines in the plan that are parallel with the plates remain the same length in the development, only those lines which are inclined or make an angle with the plate being changed.

71. To develop the dormer, Fig. 42 (c), lay off the ridge line $V''J''$ equal in length to VJ, in (a). At right angles to this line, lay off $V''H''$ and $V''E''$ equal in length to the dormer rafter. Connect H'' and J'', and E'' and J''; then $E''J''$ will be equal in length to the short valley, and $H''J''$ will be equal to $H'J'$, in (b).

Any lines laid down on either of these developments will be the true lengths of the lines, and the angles made will be the true angles. First consider the jack-rafters and roof boards in Fig. 42 (b). As all the lines in this illustration show the true lengths, it is simply necessary to scale the lengths of the jack-rafters to obtain their true length; or, the lengths may be formed by setting a bevel instrument on a square so that the blade will cross at a point equal to the distance $K'P'$ on the tongue and $H'P'$ on the body. The lengths of the different jack-rafters can be found by sliding the bevel along the tongue of the square the number of inches that the rafters are spaced feet on centers, reading the length of rafters on the body of square as shown in (d).

The lengths may also be determined by the proportion $K'P' : H'P' =$ distance between centers of jack-rafters : difference in lengths of jack-rafters.

Assuming that $K'P'$ is equal to 8 feet 6 inches, and $H'P'$ to 20 feet, and that the spacing of jack-rafters is 2 feet, then the difference in lengths of jack-rafters will be

$$8.5 \text{ feet} : 20 \text{ feet} = 2 \text{ feet} : 4.7 \text{ feet};$$

or,

$$\frac{20 \times 2}{8.5} = 4.7 \text{ feet} = 4 \text{ feet } 8.4 \text{ inches}$$

For the side cuts of jack-rafters, take the distance $K' P'$ on the tongue of the square and $P' H'$ on the body, and cut along the body. For the roof boards, use the same figures on the square, but cut along the tongue. These figures also apply to the jack-rafters and roof boards on both sides of the dormer in the main roof.

For any roof of this description, scale the distance $K' P'$, Fig. 42 (*b*), along the ridge; then, take this distance on the tongue of the square and the length of the common rafter in main roof on the body, and cut along the body.

72. For the lengths of jack-rafters in the dormer, use any of the methods just described. The proportion will be $V'' J'' : V'' H'' =$ distance between centers of jack-rafters : difference in lengths of jack-rafters. For the side cuts of jack-rafters, take the distance $J'' V''$ on the tongue of the square and $V'' H''$ on the body of the square, and cut along the body. For the roof boards, use the same figures, but cut along the tongue.

To obtain the cuts in any dormer of this description, take the length of the ridge from the plates to the intersection on the tongue of the square and the length of the common rafter in the dormer on the body of the square, and cut along the body. The jack-rafters and roof boards have the same relative positions in the developed roofs as they have in the plan. The foregoing expressions for obtaining the side cuts also hold true when the ridges are of the same height.

73. Laying Out Side Cuts for Hip Rafters.—The side cut of a hip or a valley rafter is usually more difficult to obtain than any other cut, which is especially true when the timbers are not backed. In the preceding articles, the methods of finding the side cut of hip and valley rafters have been explained, but in the examples given, the plates of the building were at right angles. In Fig. 43 is shown a plan of the roof of unequal pitch, in which one end of the roof is not at right angles and the hips on the other end are not true hips, for the reason that the plan lines of the hips

are not at an angle of 45° with the plates. The two sides have the same pitch, but the two ends pitch differently, and neither end has the same pitch as the sides; consequently, the roof has three pitches.

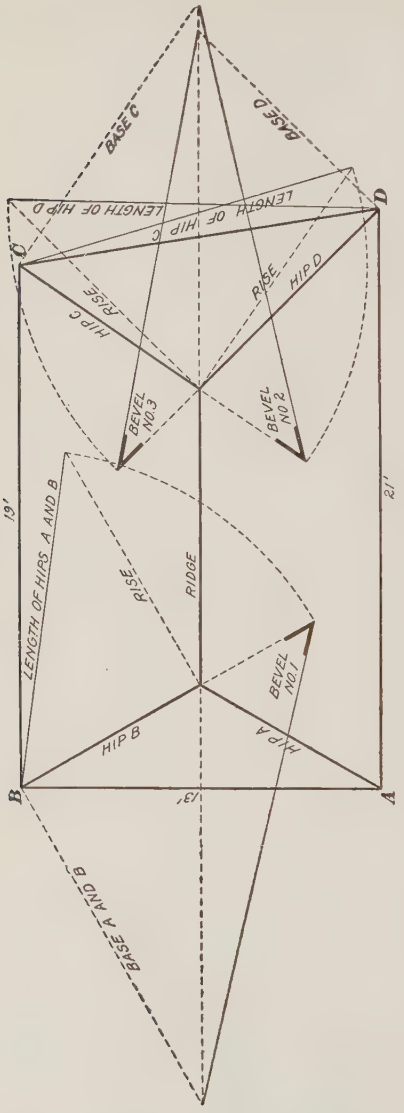

FIG. 43

The angle of bevel for the side cut of the hips at the left end, or hips *A* and *B*, is shown at bevel *No. 1*. To find this angle, erect through *B*, a right angle to the run of the hip, and project this line to the main ridge produced. Extend the seat of the hip so that it equals the length of the hip; connect this point with the point on the ridge, and the bevel for both hips is at the angle marked bevel *No. 1*. For the right-hand end, the construction is the same as for the left end.

To find the bevel for hip *C*, extend the hip *C* a distance equal to the length of the hip, then through *C* draw a line at right angles to the run of the hip, intersecting the main ridge produced; connect these two points, and bevel *No. 2* will be the correct angle to fit hip *C* against the ridge.

For the side cut of hip *D*, draw through point *D* a line at right angles to the run of hip *D*. Extend hip *D* so that it is equal to the length of hip *D*; connect these points, and bevel *No. 3* will be the correct angle to use.

74. The figures to use on the square are found by scaling the base and taking this distance on the body and the length of the hip on the tongue, cutting along the tongue. If the ends of the plates are to butt, the figures to use to get the cut will be the difference in length between the two sides on the tongue of the square and the span of the building on the body, cutting along the tongue. Thus, assume that the short side of the building is 19 feet, and that the long side is 21 feet; then, the difference will be 2 feet. Again, assume that the span of the building is 13 feet; then, 2 inches on the tongue of the square and 13 inches on the body, and cutting along the tongue, will give the angle.

75. The roof illustrated in Fig. 43 is shown developed and unfolded in Fig. 44. Assume that the sides and ends are hinged on the plates, and that it is desired to find the position that each part composing the lid will occupy when it is open and the parts are laid in a horizontal position.

To open part *A*, extend the run of the common rafters that are at right angles to the plates and equal in distance to the length of the common rafters. Connect these two points at the ends, which will give the ridge line; then, connect the points on the ridge with the corners of the plate and the end joints will be shown in their true length. These lines will correspond with the true lengths of the hip, and the part *A'* will be the true size and shape of the side *A*, and the true lines and the angles will be shown.

For part *B*, lay off the length of the common rafter at right angles to the plates, and draw the triangle *B'*. In this part, the jack-rafters are shown at right angles to the plates, which is the best way of framing them. If the jack-rafters are to be parallel with the side plates, the line length and angle will be shown by drawing lines on the part *B'* and making them parallel with the plates.

The method of developing part C is the same as that used for part A, C' showing the true size and shape.

For part D, lay off the length of the common rafter at D, making it at right angles to the plate; then, draw the triangle as shown at D'.

76. The true bevels and lengths of all the members of the roof having been shown, an expression for finding the

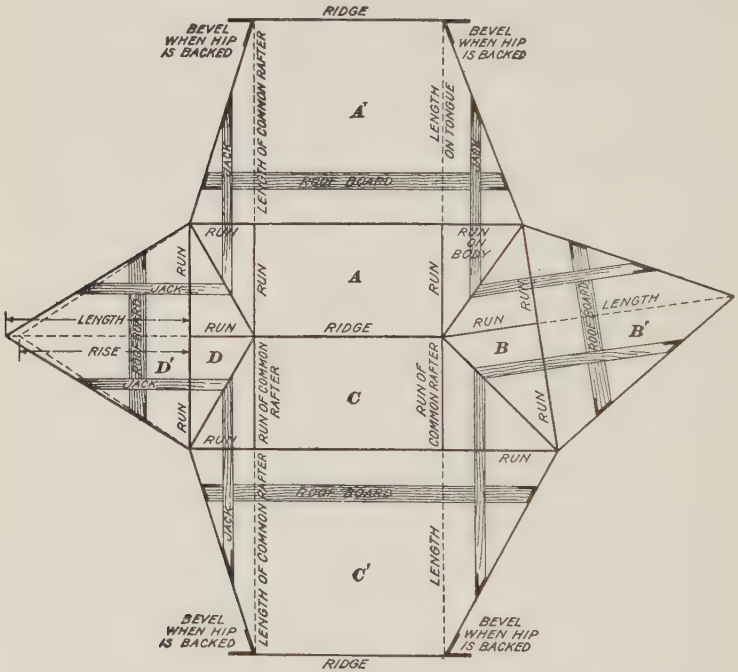

FIG 44

figures on the square may readily be taken from the drawing. Thus, the side cut of jack-rafters in A', Fig. 44, to fit against the hip in B' is run on body, length on tongue, and cut on tongue, the run and length giving the figures for each timber. It will be observed that all construction lines in the development are right-angle lines, and that these construction lines represent the true length of the common rafter in each part.

To more clearly show the size and shape of this roof, take a piece of cardboard, mark the outside lines, and then cut out the figure, making a cut along the plate lines about half way through the board; then, fold the parts A', B', C', and D' until the edges meet. In this way, the true pitches of the sides will be shown.

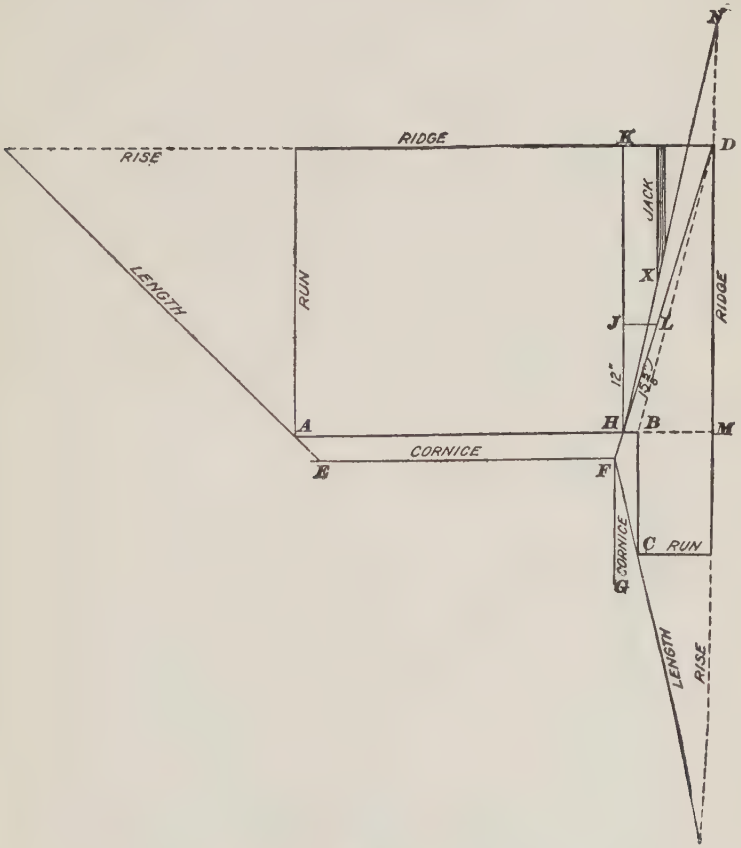

FIG. 45

77. Relation of Cornice Plate and Rafters.—Fig. 45 shows the plan lines for one-half of a roof having an unequal pitch, being similar to the roof shown in Fig. 34. The wide portion of the roof has a run of 16 feet and a rise of 16 feet

while the narrow portion has a run of 4 feet and a rise of 16 feet. The plates are shown at AB and BC. The seat of the valley, irrespective of the cornice, should extend from the intersection B of the plate to the intersection D of the two ridges, as shown by the dotted line BD, but as the cornice projects beyond the plates, as shown at EF and FG, the seat of the valley will have to be placed as shown, from F to D, intersecting the plate AB at H.

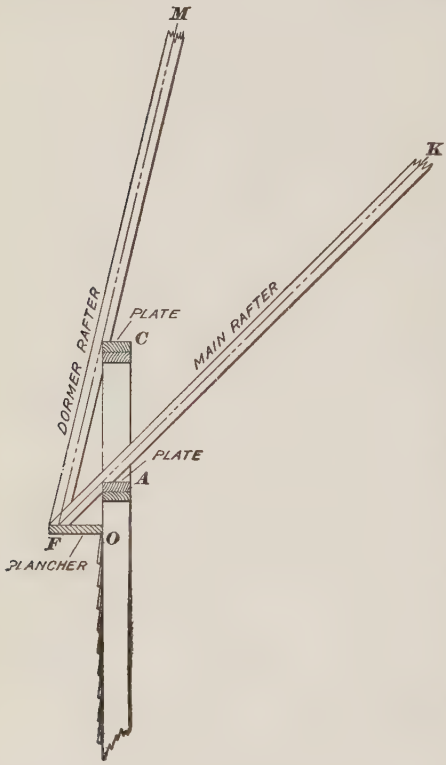

FIG. 46

To lay out the valley when in this position, its relative run to the foot-run of the rafters must be found. Let the line HJK represent the plan line and HJ the foot-run of the rafter. From J draw a line to cut the seat of the valley at L; then, LH will represent the run of the valley relative to a foot-run of the rafter.

By continuing the plate HB to M and making MN equal to the length of the rafter, a line drawn from N to H will represent the length of the valley, and its position as here indicated will define the cheek bevel of the jack-rafters, as shown at X.

To lay out the valley, take the length HL, which is the run of the valley relative to a foot-run of the rafter, on the body of the square and the rise of the roof to a foot-run, on the tongue of the square; the body will then give the foot-cut,

and the tongue, the plumb-cut. By stepping along the valley timber sixteen times, the length is determined; to this length should be added the projecting portion from the plate at *H* to the cornice line at *F*.

78. Relative Heights of Intersecting Plates.—In Fig. 46 is shown a vertical section of the rafters and plates shown at *B C*, Fig. 45; in Fig. 46, however, plate *C* is placed much higher than plate *A*. To determine the relative heights of the two plates, let *F* represent the intersecting point of the cornice. From *F* draw the pitch of the wide side of the roof from *F* to *K*, as shown. Also, from *F* draw the pitch of the narrow side of the roof from *F* to *M*. Let *F O* equal the width of the cornice, and through *O* draw the face line of the building, *O A* representing the distance from the plancher to the upper face of the plate of the wide side of the roof, and *O C*, the distance to the upper face of the plate of the narrow side of the roof. The distance from *A* to *C* indicates the difference in heights between the two plates.

DETAILS OF ROOFS AND TOWERS

79. Bevels for Square Towers.—Fig. 47 illustrates a plan and elevation of a square tower, or pyramid. The purlin line is shown at *A B*, while at *B* is shown the face bevel for the purlin. To find the miter bevel *D*, draw the line *A E* at right angles to the slant of the tower; make *A D* equal to *A C*, and connect *D E*, which will give the correct angle for the miter. The figures to be used on the square to lay out bevel *D* will be the length of *A D* on the tongue and the length of *A E* on the body, the tongue giving the cut. For the bevel *B*, take the length of *B F* on the tongue and the length of *F A* on the body; the tongue will give the cut. The line *F A* is drawn from *A* at right angles to the opposite side of the tower.

To find the face bevels, draw from *H* the line *H L* at right angles to the side of the tower, and from *K*, the line *K M* at right angles to the other side. Draw *H L'* square to *H K*.

and make it equal in length to $H\,L$. Connect $L'\,K$; then, K will be the bevel to apply to the upper face of the brace, and G will be the bevel for the side, or the plumb-bevel. These two bevels applied to the bottom end of the brace, as at G or K, will indicate how to mark the brace so as to fit the sides of the tower. The bevel at H is the side bevel for the top end of the brace, and is found as follows: From K and square to the line of brace $K\,H$, draw the line $K\,M'$, making it equal in length to $K\,M$. Connect $M'\,H$; then, the angle $K\,H\,M'$ will be the correct bevel. The other bevel is shown at J.

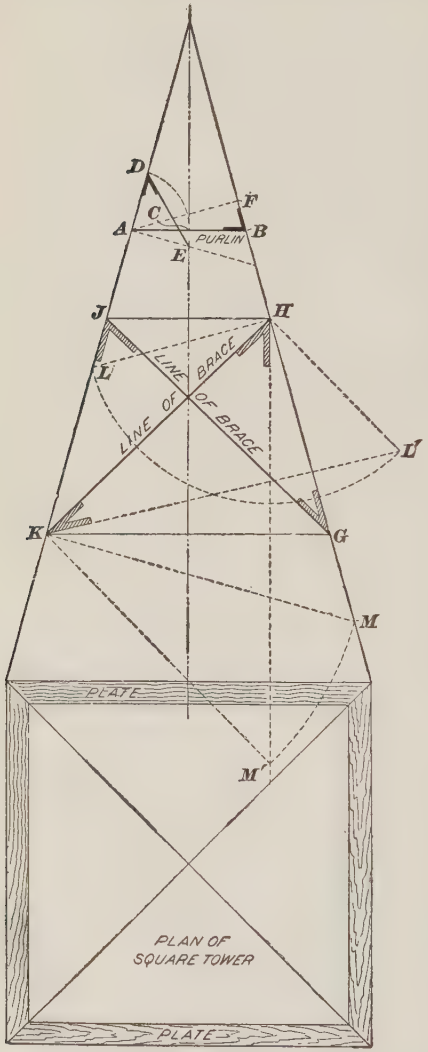

Fig. 47

80. Octagonal Roofs and Towers.—To find the figures on the square to lay out the hips of an **octagonal roof,** use the method shown in Fig. 48 which illustrates the plan of an octagonal roof. The common rafters in octagonal roofs and shed, or hip, roofs are alike. The same figures give the plumb- and foot-cuts, and the length determined in the same manner on the square.

In Fig. 48, square *No. 1* indicates a pitch of 16 inches per foot of run for the common rafter. By producing the dotted line *d* from the body of square *No. 1* to intersect the plan line of the hip *A c*, square *No. 2* placed as shown will indicate the figures *13* on the tongue and *16* on the body, which are the proper points for the rise of the hip rafter. In other words, the common rafter rises 16 inches in every 12 inches

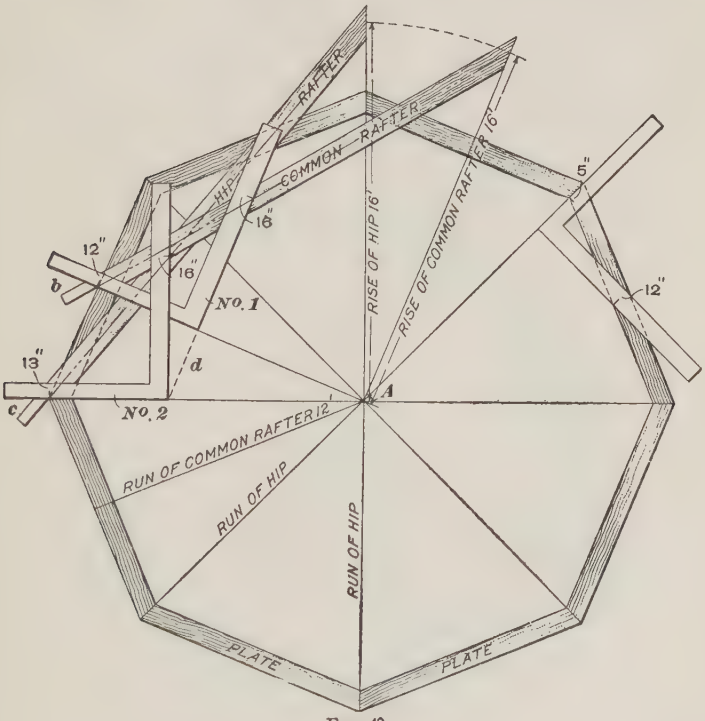

FIG. 48

of run, and the hip rafter rises 16 inches in every 13 inches of run. The 13 inches remains constant on the tongue no matter what the rise is on the body.

If the total run of the common rafter is 5 feet, the length may be found by stepping along the rafter timber five times with the figures shown on square *No. 1*; that is, 12 inches on the tongue for the run and 16 inches on the body for the

rise. The length of the hip rafter can be found by stepping along the rafter timber five times, the same as for the common rafter, but the figures on the square in this case will be 13 inches on the tongue for the run and 16 inches on the body for the rise. The foot-cut of the hip rafters will be 13 inches on the tongue and 16 inches on the body, the

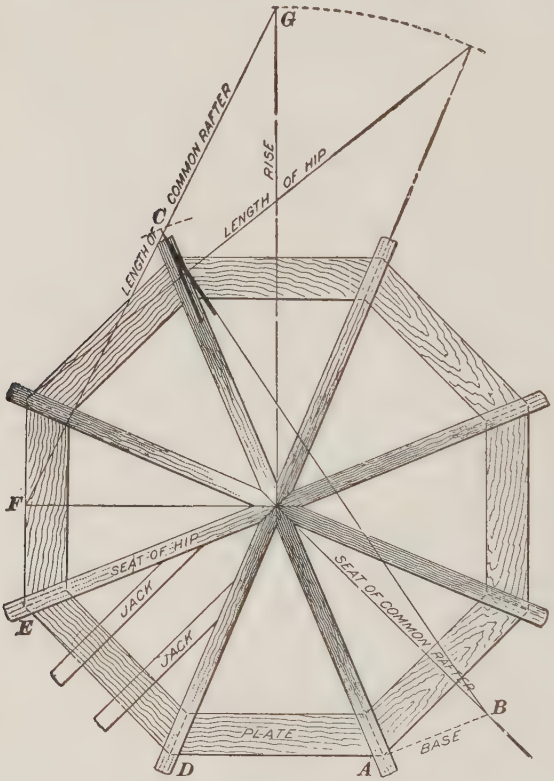

FIG. 49

tongue giving the cut; for the plumb-cut, mark along the body of the square. The figure *13* on the square is to the octagonal roof what the figure *17* is to a rectangular roof.

81. Side Cut for Octagonal-Roof Hip Rafters. There are several ways of framing the tops of octagonal

hips, and the side or cheek cut of the hip rafters will therefore depend on the method of framing. Figs. 49, 50, and 51 show three methods of framing. In Fig. 49, all hip rafters meet at a point; both sides of each rafter are cut off at an angle of $22\frac{1}{2}°$ in plan, and, if the rafters were laid level, this

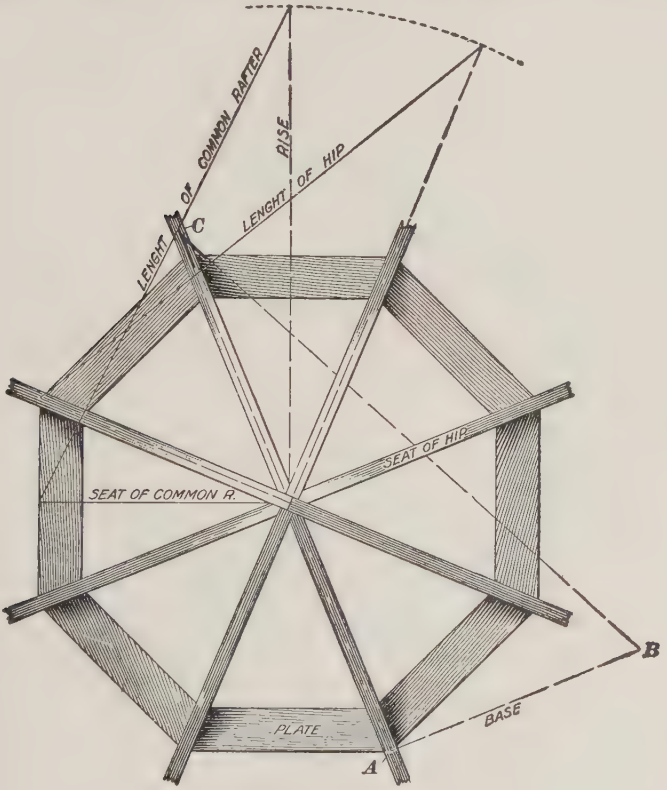

FIG. 50

would be the correct angle for the side cuts. As a matter of fact, however, the rafters are on a pitch; consequently, the side cut is less than $22\frac{1}{2}°$, and as the roof gets steeper, the angle, or side cut, becomes more acute.

To find the figures to use on the square when the hips are framed in this manner, use the following method. Fig. 49

shows the plan of an octagonal roof, with all the hip rafters in place. The rise and lengths of both the common rafter and the hip are shown. From the end of any of the hips, as at A, lay off a perpendicular to the seat of the hip, and continue this perpendicular until it intersects the seat of the common rafter produced at B. Then, from A on the seat of the hip produced, lay off the distance $A\,C$ equal to the length of the hip. Connect $C\,B$; then, $A\,C\,B$ will be the desired angle, or cheek bevel, to be used on both sides of the hip. The

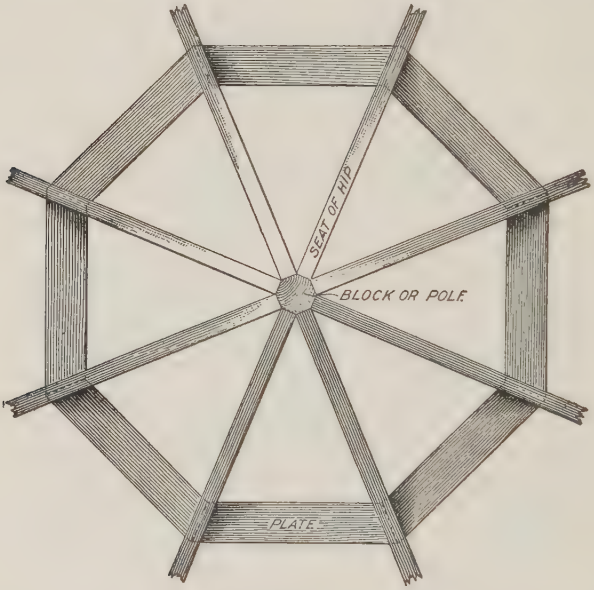

FIG. 51

figures to use on the square are the distances $A\,B$ on the tongue and $A\,C$ on the body, cutting along the body. As $A\,B$, or the base, is a constant distance per foot of run, the following rule is deduced, which will hold true for all unbacked hips framed in this manner.

Rule.—*For the cheek cut of hip rafters on octagonal roofs, take 5.38, or $5\frac{3}{8}$, inches on the tongue of the square, and the length of the hip per foot of run on the body of the square, and cut along the body.*

When the hip is backed, take 4.97, or 5, inches on the tongue of the square and the length of the common rafter per foot of run on the body of the square, and cut along the body.

82. In Fig. 50, two of the hip rafters butt against each other at their upper ends, and at right angles to them and butting against their sides are two other rafters; all four rafters have square cuts on the top. The other four rafters are framed into the angles of the first four, and have cheek cuts on both sides, the angle of cheek cut in the plan being 45°. The method of obtaining the true cheek cut is the same as explained in the preceding article, with the exception that in this case the base is carried to the seat of the hip produced. The figures to use on the square are found by taking the distance AB, or the base, on the tongue, and the distance AC, or the length of the hip, on the body, the body giving the cut.

The following rule will hold true for the side cut of the four hip rafters, if unbacked, when framed in the manner described.

Rule.—*Take 13 inches on the tongue of the square and the length of the hip per foot of run of common rafter on the body of the square, and cut along the body. When the hips are backed, take 5 inches on the tongue of the square and the length of the common rafter per foot of run on the body of the square, and mark along the body; then, apply the square, to this mark, using the same figures, and cut along the body.*

83. Fig. 51 shows a plan of an octagonal roof in which the hips are framed to an octagonal block, or pole, in the center. When rafters are framed in this manner, the only cut at the top is the plumb-cut.

84. Octagonal-Roof Jack-Rafters.—Fig. 52 shows a developed side of the roof illustrated in Fig. 51. To make this development, lay off GF equal in length to the common rafter; from F and at right angles, lay off FD and FE, each equal to one-half the length of one side of the octagon. Connect G and D, and G and E; then, these two lines will be

the correct length of the hips, and the triangle EGD will be the true size and shape of one side. Furthermore, all the members of the roof will be shown in their true lengths, and the angles found will be the true angles.

For the side cut of the jack-rafters to fit against the hip, take the distance FD on the tongue of the square and the length of the common rafter FG on the body of the square, and cut along the body. For the side cut of any octagonal jack-rafter, take 5 inches on the tongue of the square and the length of the common rafter per foot of run on the body of the square, and cut along the body.

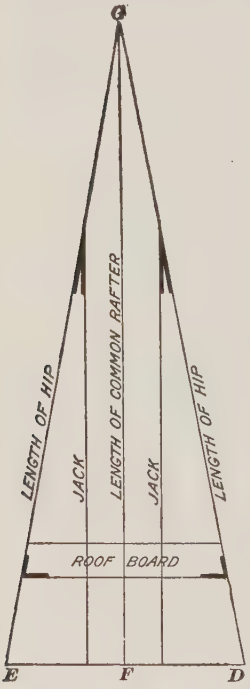

FIG. 52

The true length of the jack-rafter is shown in this illustration. To obtain the difference in lengths of jack-rafters in any octagonal roof, use the following proportion: 5, or 4.97, inches is to the length of the common rafter per foot as the spacing, in inches, is to the difference in length; or, multiply the length of the common rafter per foot of run by .201 and then by the spacing in inches. Thus, the length of the common rafter per foot of run in a 16-inch pitch is 20 inches. If jack-rafters are spaced 16 inches on centers, then the difference in the length will be in the first case, $4.97 : 20 = 16 : 64.4$; in the second case, $20 \times .201 \times 16 = 64.32$ inches. That is, the first jack-rafter next to the common rafter will be 64.32 inches shorter than the common rafter, the second jack-rafter will be 64.32 inches shorter than the first jack-rafter, and so on.

The cut of the roof boards to fit over the hips can be obtained by using the same figures as for the side cut of jack-rafters, but the cut must be made along the tongue of the square.

85. Backing Hips for Octagonal Roofs.—Fig. 53 shows two methods for obtaining the figures on a square to back the hip rafters on an octagonal roof. The method shown on the left side of the illustration is applicable to all hips, even when the bevel is not the same on both edges. Lay off the line $A\,C$ equal to the rise of the rafter, and connect B and C. From any point on $B\,C$, as at D, erect a perpendicular to $B\,C$, intersecting the seat of hip in E. Through the point E, draw the line $J\,H$ parallel with the pitch of the rafter; also, through E erect a perpendicular to the seat of the hip, intersecting the plate line, or the plate line produced. In this case, the perpendicular intersects the plate line at G. Make $E\,H$ and $E\,J$ each equal in length to $E\,G$. Connect D and H, and D and J; then, the angle $E\,D\,H$ will be the proper bevel for one side of the hip, and the angle $E\,D\,J$, which in this case is equal to $E\,D\,H$, will be the proper bevel for the other side. The figures to use on the square are the distances $E\,H$ on the body and $E\,D$ on the tongue, cutting along the tongue.

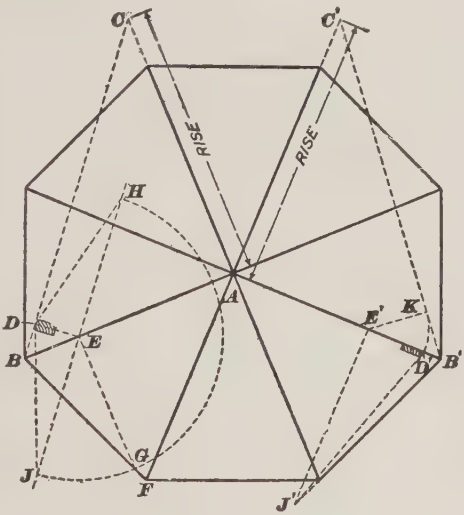

FIG. 53

86. The method shown on the right in Fig. 53 is applicable only when both sides of the rafter are backed with the same bevel. At K, on the pitch line $B'\,C'$, erect a perpendicular intersecting the seat of the hip $A\,B'$ at E'. From E', and at right angles to the seat of the hip, draw $E'\,J'$, intersecting the plate line produced. Connect J' and D', and the

angle $J'D'E'$ will be the bevel. The figures on the square are the distances $E'D'$ on the tongue and $E'J'$ on the body. Cut along the tongue.

This method may be used for any regular polygon, while the first method can be used either for a regular or for an irregular plan.

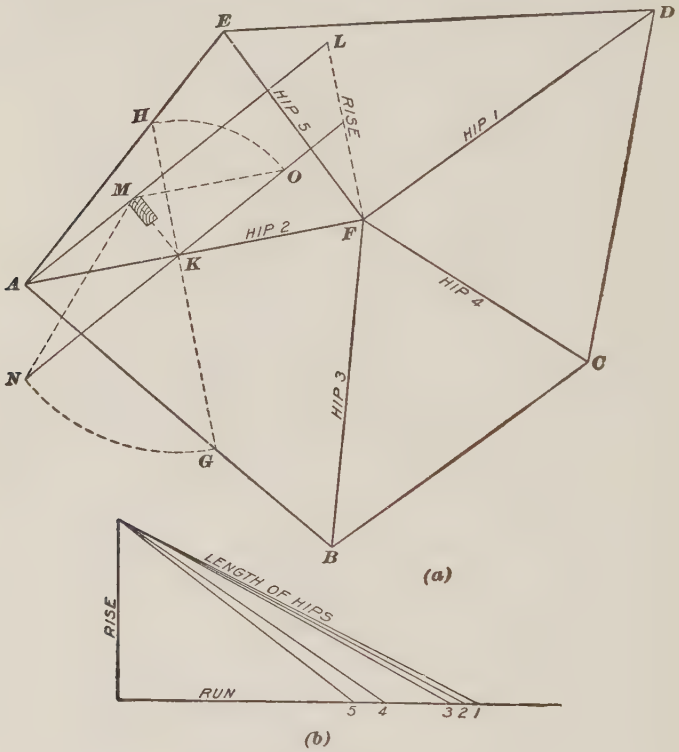

FIG. 54

87. The first method applied to an irregular plan is shown in Fig. 54 (*a*). $ABCDE$ is the plan of a hip roof containing five hips, no two of which have equal lengths, but all of them have the same rise; consequently, no two of the roof surfaces have the same pitch.

To find the backing for both sides of hip *No. 2*, make FI equal to the rise, and connect L and A. From any point on

the line $L A$, draw $M K$ at right angles to $L A$, the point K being in the seat line $A F$. Through K and at right angles to $A F$, draw $G H$; also, through K and parallel with the pitch of the rafter $A L$, draw $N O$. Make $K O$ equal in length to $K H$, and $K N$ equal to $K G$.

Connect M and O, and M and N. The angle $K M O$ is the bevel to apply on the side H of the rafter, and the angle $K M N$ is the bevel to apply on the side G.

The figures to use on the square are the distances $M K$ and $K O$, for the H side of the rafter, and $M K$ and $K N$ for the G side, $M K$ giving the cut in both cases.

Incidentally, in (b) is shown a short method of finding the lengths of all the hips.

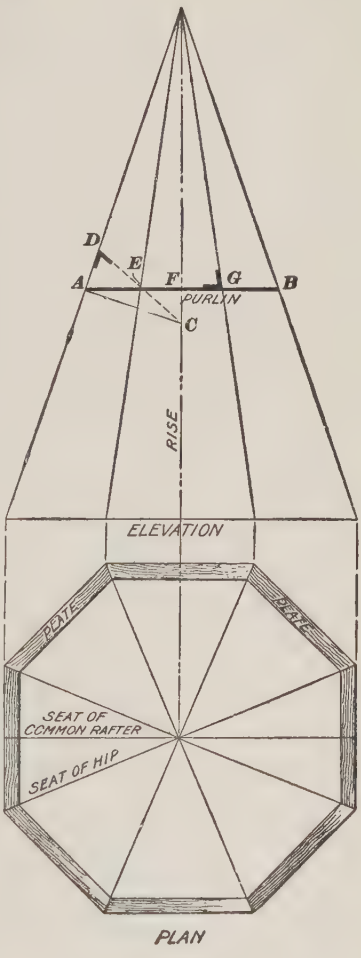

FIG. 55

88. Purlins for Octagonal Towers.—The plan and elevation of an octagonal tower is shown in Fig. 55, the line $A B$ representing the line of purlin. To find the bevels, draw the line $A C$ at right angles to the pitch, or slant, of the side. Make $A D$ equal to $E F$, and connect D to C. The angle shown at D will be the down cut of the purlin, and that shown at G will be the face cut. The figures on the square for bevel D are the length $A D$ on the tongue and the length $A C$ on the body, the tongue giving the bevel.

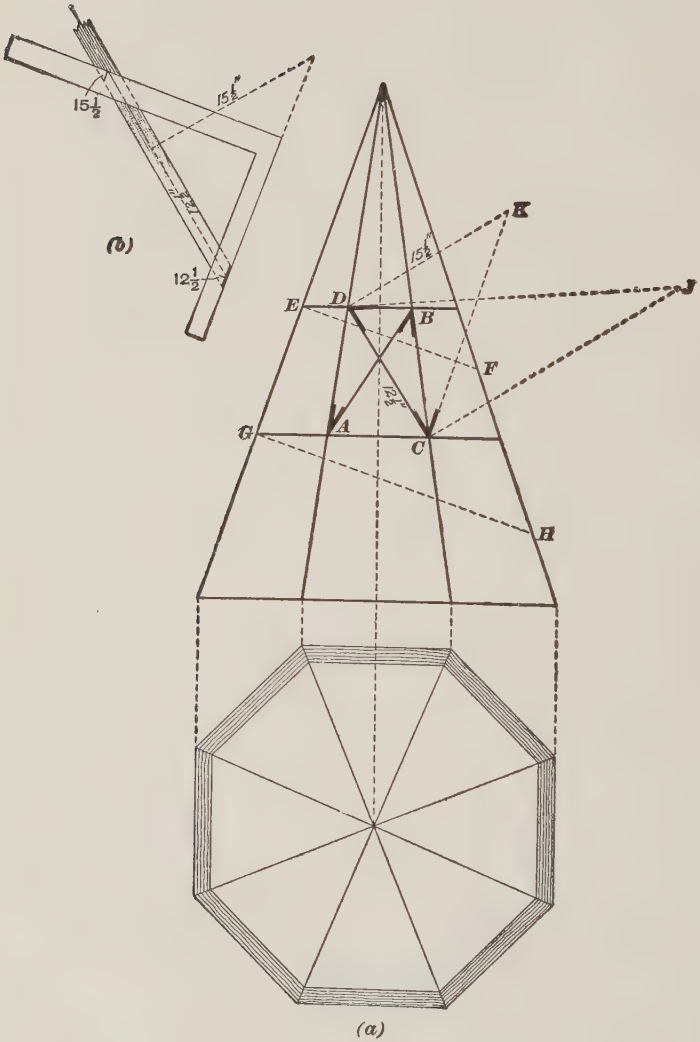

FIG. 56

89. Brace Bevels for Octagonal Towers.—The method of finding the brace bevels for an octagonal tower is similar to finding the same bevels of a square tower. Fig. 56 (*a*) shows the plan and elevation of an octagonal tower. The lines *A B* and *C D* represent the lines of braces. From *E*, draw the line *E F* at right angles to the pitch of the tower, and from *G* draw the line *G H* at right angles to the same side. Draw *D K* at right angles to the brace line *C D*, and make it equal in length to *E F*; connect *K* to *C*. From *C* and at right angles to the brace *C D*, draw *C J*, making it equal in length to *G H*; connect *J* to *D*. The bevels shown at *A* and *B* are to be applied to the side of the braces, and those shown at *D* and *C*, to the upper face, or back of the braces, *D* being applied to the upper and *C* to the lower end of the brace. It will be noticed that bevels *A* and *B* are in the angles between the brace line *A B* and the two hips.

In (*b*) is shown how to apply the square to obtain the cut for the bevel at *C*.

90. Framing Hexagonal Roofs.—In Fig. 57 are shown the plan lines of a hexagonal roof or tower. The method of finding the figures on the square to obtain the lengths and cuts of rafters is the same as that for framing octagonal roofs. The figures on square *No. 1* indicate that the common rafters rise 20 inches per foot of run. By placing square *No. 2* on the seat of the hip, with its heel on the line of the body of square *No. 1*, the figures on square *No. 2* giving the pitch of the hip rafter will be found to be $13\frac{7}{8}$ inches on the tongue for the run, and 20 inches on the body for the rise. The cuts will be found by marking along the tongue for the foot-cut and along the body for the plumb-cut. The length will be found by stepping along the timber the number of times that the common rafter contains feet in its run.

The common rafter in a hexagonal roof is the same as in an ordinary roof. The figures $13\frac{7}{8}$ are to the hexagonal hip what *13* is to the octagonal hip or *17* is to the rectangular hip.

The method of finding purlin and brace bevels is the same in the hexagonal roof as in the octagonal roof.

91. Side Cuts of Hexagonal Hips.—The method of finding the side cuts for hexagonal hips is the same as for octagonal hips. There are a number of ways of framing the top ends of the hips, but as the method of finding the

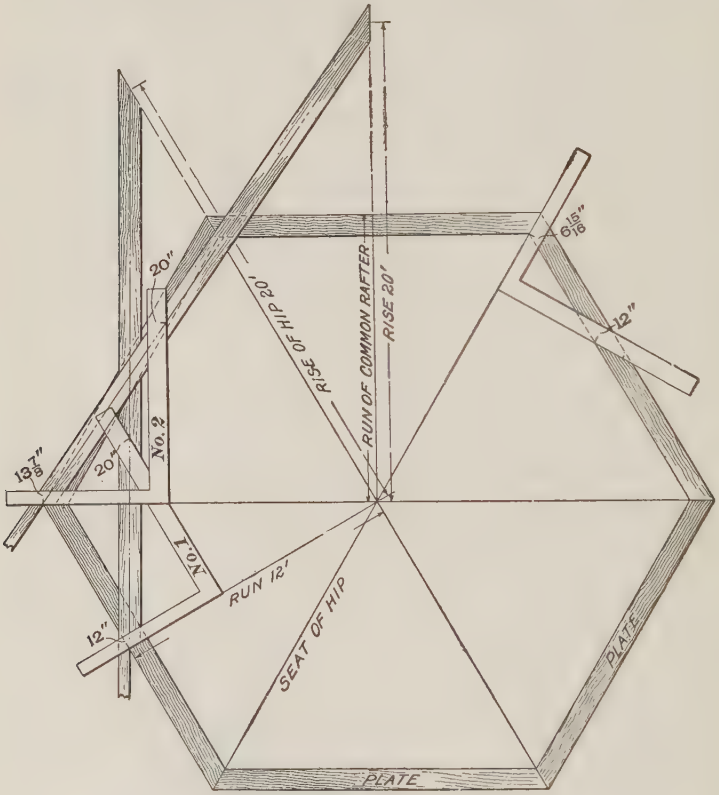

FIG. 57

figures to use on the square is the same as for octagonal hips, the expressions on the square will be given without a demonstration of the principles.

Fig. 58 shows four ways of bringing the tops of the hips together. In (*a*) all the hips are framed to a point, and the

side cuts are the same on both sides of the six rafters. The figures to use on the square to obtain these bevels are 8 inches on the tongue, and the length of hip per foot of run on the body. Cut along the body. If the hips are backed, take 6.92, or $6\frac{15}{16}$ inches on the tongue of the square, and the

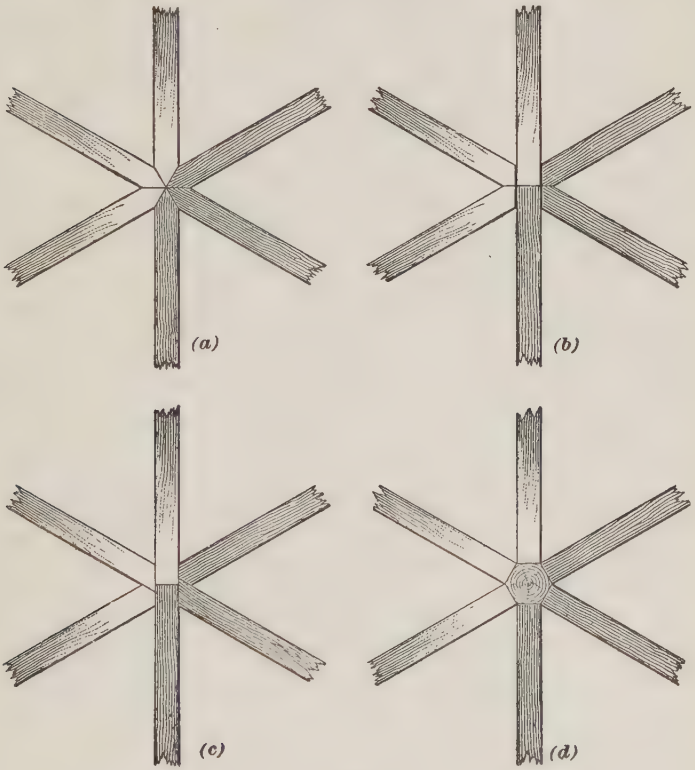

FIG. 58

length of the common rafters per foot of run on the body, and cut along the body.

92. If the hips are framed as in Fig. 58 (*b*), two of the hips will butt against each other and the only cut will be the pumb-cut. The cuts for the other four hips are similar to each other. They have a cheek cut on both side, but these cuts are not the same. The cheek cut on the side that

fits against the butting hip is found by taking 12 inches on the tongue of the square and one-half the length of the hip per foot of run on the body of the square, and cutting along the body. The cut for the other side of the hip is the same as when the hips meet at a point, that is, 8 inches on the tongue of the square, and the length of the hip per foot of run on the body of the square. In this case, the cut is along the body. If the hips are backed, take 6.92 inches on the tongue and the length of the common rafter per foot of run on the body, and mark along the body; then, apply the square to this mark, using the same figures as before, and cut along the body for the side to fit against the butting hip. For the other side, take 6.92 inches on the tongue and the length of the common rafter per foot of run on the body of the square, and cut along the body.

93. If the hips are framed as in Fig. 58 (*c*), two of the hips butt against each other as in (*b*). The other four hips have the same cuts; two of them have the cut from one side only, and the other two have the same cut on both sides. This latter cut is the same as for the side cut of the hip to fit against the butting hip in (*b*), that is, 12 inches on the tongue of the square and one-half the length of the hip per foot of run, on the body of the square. The cut is along the body. When the hips are backed, the side cut is 6.92 inches on the tongue, and the length of the common rafter per foot of run on the body and mark along the body; then apply the square to this mark, using the same figures as before. The cut is along the body. Apply this cut to each side of the two rafters, and to one side only of the other two rafters.

94. In Fig. 58 (*d*) is shown the hip framed to a center pole or block. In this case, the plumb-cut only is necessary.

95. Jack-Rafters and Roof Boards for Hexagonal Roofs.—The method of finding the figures on a square for the side cuts of jack-rafters in hexagonal roofs is the same as that used for finding the cheek cuts for jack-rafters in octagonal roofs, as already explained. The rule that holds true for all hexagonal roofs, regardless of pitch, is as follows:

Rule.—*To find the cheek cut for a jack-rafter on a hexagonal roof, take 6.92 inches on the tongue of the square and the length of the common rafter per foot of run on the body of the square, and cut along the body.*

For the roof boards, use the same figures on the square, but cut along the tongue.

The difference in lengths of jack-rafters in hexagonal roofs, is expressed by the following proportion: 6.92 is to the length of the common rafter per foot of run as the spacing, in inches, is to the difference in length. For example, take a roof with a pitch of 16 inches in 12 inches, in which the jack-rafters are spaced 16 inches on centers. For this pitch, the length of the common rafter is 20 inches per foot of run. Then, 6.92 inches : 20 inches = 16 inches : 46.24 inches; or, $\frac{20 \times 16}{6.92} = 46.24$ inches, which is the difference in length. The difference may also be found by multiplying the length of the common rafter per foot of run, by .144 and by the spacing in inches; thus, in the preceding case, $20 \times .144 \times 16 = 46.08$ inches.

Set a bevel instrument at 6.92 inches on the tongue of the square and 20 inches on the body. Slide the instrument to 5.59 inches on the tongue, and the body will read, 16.15, which, subtracted from 20 feet, leaves 3.85 feet, or 3 feet 10.2 inches, or 46.2 inches. The 5.59 is obtained by subtracting 16 inches, or 1.33 feet, from 6.92. If the common rafter is 20 feet long, then the jack-rafter next to the common rafter will be 16.15 feet, or 16 feet 1.8 inches, long.